Evaluating Price Impacts for Stated Attributes of Western Canadian Feeder Calves Marketed via Online Auction

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Abstract

This research provides insight on the value of attributes for feeder calves sold via electronic auction in Western Canada from 2016 to 2020 during the months of August to December. Results from this research can provide producers with valuable information to market their feeder calves more effectively. By identifying attributes buyers value and attributes that are less desired and associated with price discounts producers can make more informed marketing and management decisions.

Lot description details and sales results for 4,866 feeder calf lots (3,235 steer and 1,631 heifer) representing 505,074 head were analyzed using a hedonic pricing model with OLS regression to estimate the price impacts of 17 attributes. The model variables considered lot (gender, number of head, province of origin), genetic (hide colour, frame size), management (weight, weight uniformity, flesh, implant use and weaning status), marketing (age verification, VBP+ mention, EU eligibility) and market structure (marketing week, days to delivery, expected fed price) characteristics. Steer and heifer lots were estimated separately, with a pooled model and five annual models for each sex.

Traditional feeder calf attributes - weight, lot size and weight uniformity - showed consistently statistically significant results. Marketing attributes – VBP+ and EU Eligibility – only estimated price premiums in the last two years of the steer model. From 2016 to 2020 the percentage of lots mentioning VBP+ increased from 3% to 15% and the percentage of lots noting EU eligibility increased from 0% to 8%. Lack of significance for value-added marketing attributes may be related to a lack of third-party verification for claims made on lot listing reports. The percent of lots mentioning age verification declined 12% from 2016 to 2020 and the premium declined from 2017 to 2019 for steer lots. In all models Charolais-influenced calves received premiums while steer lots with mixed colours were discounted compared to black-hided lots. It can be concluded from the results that feeder calves marketed in larger, more uniform lots with implant status disclosed receive higher prices in the western Canadian online auction market. It is important for sellers to provide all information for a lot of calves when marketing online as buyers value information on attributes when making purchasing decisions.

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Chapter 1. Introduction

1.1 Introduction

Cow-calf producers are an essential link in the beef supply chain. Conventional beef production is the production of commodity beef where numerous sellers market calves to the same buyers. If individuals can differentiate their calves from other producers, they may be able to extract a higher market price. Cow-calf producers are heterogenous in their management styles and practices, for example producers can differentiate themselves through seasonal calving, weaning method, health and vaccination programs, breed and industry initiatives (USDA, 2020; BCRC, 2019). Producers are faced with many value-added options and management decisions that could be implemented into their calf production and marketing practices. In the 2017 Western Canadian Cow-Calf Survey, 71% of survey respondents reported profitability as one of their main objectives (University of Saskatchewan, 2018). The majority of cow-calf producers are motivated to make a profit; they will adapt management practices and include value-added attributes into their programs if monetary benefits exist for doing so (Young & Shumway, 1991; Popp et al., 1999). Aside from making a profit, producers also consider individual operating goals, the environment and available resources when making management decisions (Hawkes et al., 2008). In order for cow-calf producers to make efficient production and marketing decisions they need information on which feeder calf attributes are valued by buyers.

Producers need information on what to expect from introducing value-added attributes or making management changes to their programs. Increased costs are often associated with value-added opportunities, and producers need evidence to support potential profits or losses of implementing these practices.

Previous research has shown there are certain traits and attributes that are valued by buyers (Faminow & Gum, 1986; Bulut & Lawrence, 2007; Blank et al., 2009; Seeger et al., 2011; Zimmerman et al., 2012; Carlberg & Hogan, 2013; Schulz et al., 2015). There are both traditional and value-added attributes shown to influence feeder calf prices. The following are traditional attributes shown to influence calf prices: lot size (number of head), weight, weight variation, frame, flesh, breed, hide/coat colour, days to delivery, health, presence of horns, weaning status, cattle futures and the location of the cattle. Value-added attributes include, but are not limited to, implant status, marketing to branded beef programs, no antibiotic or growth enhancing hormones used (natural)[1], Verified Beef Production Plus (VBP+) certification, and EU export certification. Despite the large body of research in the US little is known about the feeder calf attributes buyers value in western Canada.

1.2 Research Objectives

This research used a hedonic model with OLS regression to determine the value of attributes and management characteristics for western Canadian feeder calves marketed via online auction.

The study focused on the following objectives:

1. Review the existing literature on feeder cattle price hedonics to develop a model suitable to analyze Western Canadian online auction data.
2. Provide insight on the price impacts of traditional and value-added lot attributes for feeder calves sold via online auction in Western Canada.
3. Report how the declaration of value-added attributes for online auction feeder calf listings has changed from 2016 to 2020.
4. Identify trends for the value of specific calf attributes. For example, are there certain attributes that are consistently significant every year of the study or do the importance of attributes differ over time.

This research provides insight on how western Canadian feeder calves are valued based on attributes and management characteristics. Findings from this research will help cow-calf producers to make informed management decisions.

1.3 Project Overview

Data for the analysis was sourced from the pre-sale lot listing reports for online feeder calf auctions operating in Western Canada; namely, TEAM (The Electronic Auction Market), DLMS (Direct Livestock Marketing Systems), SALE (Southern Alberta Livestock Exchange) and fall specialty sales in Alberta (e.g., Balog, Dryland, Cudlobe Angus). In online auctions each feeder calf group

[1] The term "natural" refers to beef that has been raised without the use of growth promoting hormones or antibiotics.

(lot) sold originates from one operation. Prior to the sale, details are collected about the animals for sale in a lot and shared with potential buyers via the lot listing report posted on an auction company's website. The provision of lot details prior to and during an online auction increases transparency between the seller and buyer and reduces information asymmetry.

Each lot varies in its attributes. Hedonic regression analysis can provide insight on which feeder calf attributes are valued or discounted by buyers. Lot attributes and sales data for western Canadian feeder calves marketed through online auction each fall from 2016 to 2020 were compiled into a database for the analysis. A hedonic pricing model paired with OLS regression, resulted in a series of econometric models to explain price determinants for feeder calves. The analysis determined the statistical significance and economic value of premiums and discounts for each lot attribute.

1.4 Industry Benefit

Livestock auction markets are an important tool used by many producers to market their calves. It is important to note that there is a relatively small number of cow-calf producers in Western Canada who are marketing calves through online auction, for many producers live auction markets are still the marketing method of choice. However, this research is only possible using online auction data, due to the detailed lot listing reports that are available from prior years. Online auctions represent the market behavior of buyers and sellers in the feeder calf market and are comparable to live auction markets. This study identified price effects for various attributes that cow-calf producers can directly implement on their operations. To the author's knowledge this is the first Canadian study of its kind to utilize multi-year data, as such this research is expected to open opportunities for beef industry to further explore and expand on the ideas presented in this thesis.

1.5 Organization of the Thesis

This thesis is divided into nine chapters. Chapter 1 provides an introduction and explanation of the thesis, while Chapter 2 provides an overview of the Canadian beef supply chain, with a focus on cow-calf production, options for marketing calves, and an explanation of the online lot listings and online auction platforms. Chapter 3 includes a literature review on feeder calf pricing and modeling, discussion on the hedonic model, previous Canadian and American studies, and a detailed overview of factors shown to influence the price of feeder calves in previous research. Chapter 4 includes the theoretical framework that supports this thesis and the research being conducted. Chapter 5 includes the methodology, description of the data and various model characteristics. Chapter 6 is the estimation of the model, where the model is introduced, specified, and tested for various econometric issues. Chapter 7 reports the results for the model. Chapter 8 includes the implications and discussion of the model results and finally Chapter 9 will summarize and conclude the thesis.

Chapter 2. Canadian Beef Industry Overview

As of the 2016 Census of Agriculture there are 53,837 farms with beef cows in Canada with 61% (32,933) of the farms located in the provinces of British Columbia, Alberta and Saskatchewan (Statistics Canada, 2016). The provinces of Saskatchewan and Alberta account for over 70 percent of the total beef cows in Canada (Statistics Canada, 2021). Alberta has 156 feedlots with a combined feeding capacity of 1.53 million head and accounts for nearly 70 percent of Canada's fed cattle production (Canfax, 2021a; Canfax, 2021b). Three federally-inspected packing plants in Alberta – JBS, Cargill and Harmony Beef – account for 71 percent of the federally-inspected slaughter capacity in Canada (Canfax, 2021). The western Canadian beef supply chain is highly concentrated in Alberta.

2.1 Cow-Calf Production

The average beef cow herd size in western Canada is approximately 90 cows. As Figure 2-1 shows, over 50% of herds have less than 47 cows while only 6% have over 273 cows (Statistics Canada, 2016). Commercial cow-calf producers maintain a herd of brood cows with the purpose of raising and selling calves each year. A recommended practice is to limit the number of days breeding females are exposed to bulls to 63 days to manage the calving period. A defined calving season of 60 to 80 days allows producers to have more even and uniform calves to market (Alberta Agriculture and Food, 2008). Western Canadian beef producers are typically spring calving (Beef Cattle Research Council, 2019). Mother cows nurse their calves throughout the summer on pasture grass. Each fall when calves are approximately six to eight months of age they are weaned off their mothers and started on feed; weaned calves can range in weight from 550 to 900 pounds (Alberta Agriculture and Food, 2008; Canadian Cattleman's Association, 2013). Most weaned calves enter the beef supply chain as feeder cattle where they are fed until they have reached slaughter weight (1,300 to 1,500lbs) and then processed into beef products. Heifer calves have the potential to become new breeding stock and enter cow herds as replacement heifers.[2] About 40% of heifers are developed into replacement breeding stock (Statistics Canada, 2021a). Heifers that are not

[2] Replacement heifers are female calves that will be added to a cow-calf operation as new breeding stock. Replacement heifers are often higher quality animals that have more desirable traits that cow-calf producers would like to introduce into their breeding herds.

replacement-quality are called feeder heifers and will enter the supply chain to be fed and harvested for beef.

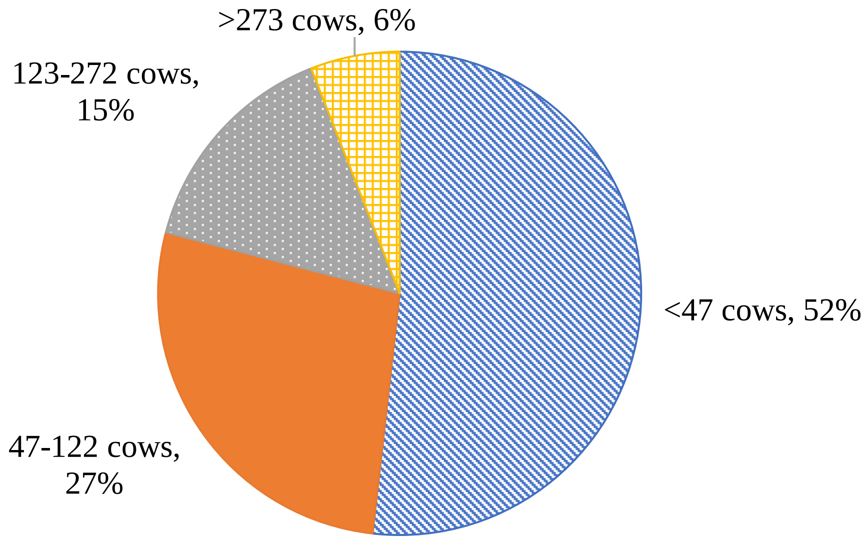

Figure 2-1. Percent of Farms by Beef Cow Herd Size in Western Canada, 2016 Census
Source: Statistics Canada, 2016

According to the 2017 Western Canadian Cow-Calf Survey, close to 70% of producers sell a portion of their calves at weaning each year with almost 50% of producers weaning calves in late October to early November (University of Saskatchewan, 2018). During this time an abundant supply of calves are marketed, this is commonly called the "fall-run"[3] which includes calf sales from September through December. During the fall-run a large majority of cow-calf producers market their calves, causing supply to exceed demand, resulting in falling prices (see Figure 2-2). Implementing specific management practices and attributes is a way for producers to differentiate their feeder calves in this crowded market in the hopes of obtaining higher prices.

[3] The term "fall-run" is commonly used to describe the time period of September through December when a large majority of weaned calves are sold. During the fall-run live auction markets, online auction markets and auction representatives are busy marketing and listing calves to be sold.

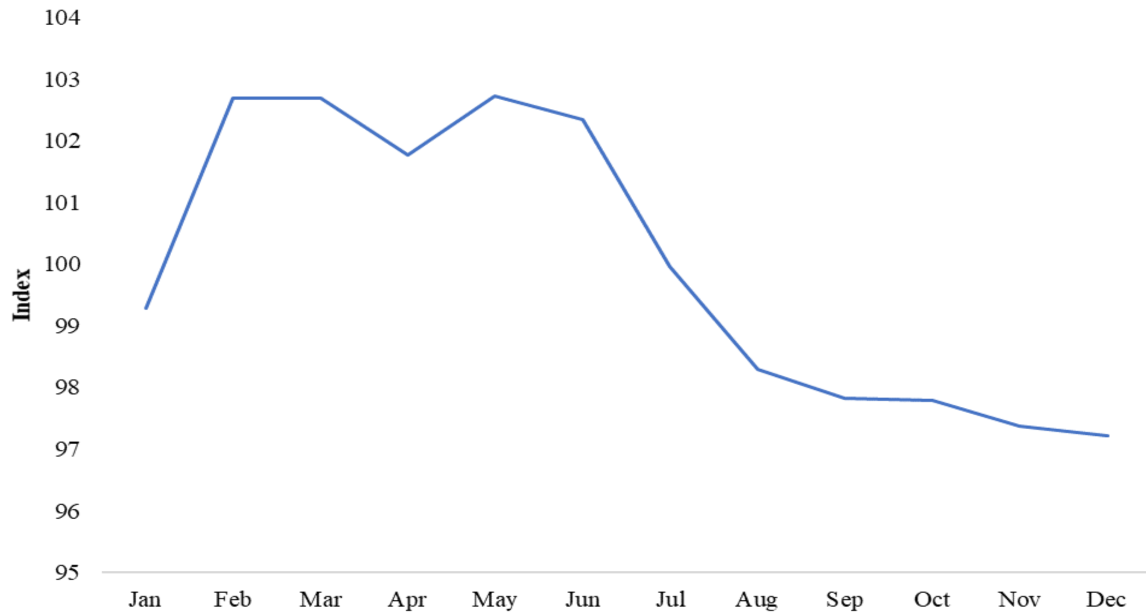

Figure 2-2. Ten Year Price Seasonality Index for Alberta 550 lb Steer Calves, 2010-2020
Source: Canfax, 2021c

2.2 Market Volatility

Market volatility can be defined as the velocity of price changes for any market that includes commodities (Amadeo, 2020). The beef market is uncertain, prices fluctuate up and down with changing consumer demands, market seasonality, futures prices and the supply of beef available in the market. As much of the existing hedonic research has been done in the US, regional market volatility has a larger impact on the beef market in the US due to the varying geographic regions beef production takes place. Production regions in the US may face drastically different weather and environmental conditions, causing more market volatility in the feeder calf market within different US regions (McCabe, 2018). The Canadian beef industry is essentially split into two markets, the east and the west, this research will focus on the Western Canadian beef market. The majority of Canadian beef is fed and processed in Alberta (68.6% AB and 10.2% in BC, SK, MB), with 77 percent of Canada's beef cows residing in Alberta, Saskatchewan and British Columbia *(Canfax, 2020)*. The Prairie provinces are close in geographical proximity therefore the province of origin of the cattle in Canada should have less of an impact on the market prices.

Beef production goes through cycles that traditionally last for 7 to 13 years, the cycle itself is influenced by production, prices, and profits. The cattle cycle can predict herd expansion and contraction (Canfax, 2018). The cattle cycle is influenced by both domestic and international consumer demand for beef, trade agreements, market access, the biological process of beef production, yearly weather conditions, input prices and market prices. There are four distinct phases in the typical cattle cycle:

1. **Consolidation:** During this phase producers consolidate their herds and keep only high quality, profitable animals. This phase usually lasts one year, but under adverse economic circumstances it may last two to three years.
2. **Expansion:** During this phase producers grow their herds and increase the number of cattle they manage, at this time market prices are strong. Normally the expansion phase will last five years, but it can be up to two years shorter or three years longer.
3. **Peak:** During the peak year cattle prices see a strong increase. This phase is hard to predict as it is largely influenced by outside factors such as domestic and international beef demand and production costs.
4. **Liquidation:** During this phase markets have come down from the peak year and prices are lower. Producers start liquidating the number of cattle they manage. This phase normally lasts for two or three years.

(CanFax, 2018)

Cattle producers are at a disadvantage in terms of responding to market signals. The production cycle for beef cattle is a longer process than other proteins such as poultry and pork. Cattle producers are unable to respond immediately to market signals. The longer biological production cycle causes delayed response time for beef producers and puts them at a disadvantage in terms of rapidly changing markets (Canadian Roundtable for Sustainable Beef, 2016).

Canfax has identified the cattle cycle from 2012 to current as the “The China Effect”, where in 2014 and 2015 calf prices surged due to strong domestic and international demand for beef (Canfax, 2018). China’s imports of Canadian beef were strong which in turn supported record high cattle prices globally. The growing middle class in countries such as China are driving the increase in beef demand, as incomes rise consumption of protein from higher quality sources such as beef, increases.

Multiple cases of African Swine Fever have been reported in China since the summer of 2018. Hogs infected with African Swine Fever must be destroyed; this outbreak caused a substitution effect where consumers substituted pork for alternate sources of protein such as beef (Canfax, 2018). Epidemics in one protein can cause consumers to shift their demand to an alternate protein, in the case of African Swine Fever, consumers demanded more beef and exports of Canadian beef increased.

2.3 Options for Marketing Calves

Three common ways to market calves are live auction (at a sale barn or auction mart), online auctions, or private treaty agreements. Live auction is the marketing method of choice for most cow-calf producers, but the use of electronic auctions is growing in popularity (Beef Cattle Research Council, 2019). Electronic auctions sold an average of 308,000 head per year between 2016 to 2020; annual electronic volumes increased by 41 percent from 2016 (264,550 head) to 2020 (373,850 head) (Canfax, 2020). Some reasons producers may prefer to utilize live auction markets are to support the local business; if they have fewer calves to sell; for convenience, their geographical location or if they could benefit from pre-sort sales.[4] Online auctions may appeal to producers with a larger number of calves to market who could benefit from selling their calves as a select group from one operation. Online auction allows producers to promote their calves' attributes through the lot listing reports. Producers may also choose online auction due to their geographical location and convenience. Some producers may not have a live auction market nearby to sell their calves and therefore online auction is the preferred method; each operation is different and benefits to marketing methods vary by producer.

There are 41 live auction markets in Western Canada (BC, AB, SK, MB) and two exclusively online auction markets, DLMS and TEAM (Canfax, 2008). An online auction market allows buyers and sellers from any location the opportunity to coordinate via the internet. Online auctions are particularly appealing for larger producers who have enough calves of the same sex and weight

[4] Pre-sort sales occur at live auction markets. Producers deliver their calves to the auction market the day prior to the sale. Calves are sorted into groups based on weight, quality, and conformation, therefore calves from multiple consignors are comingled and sold together.

to fill a liner load.[5] Online auction markets also give buyers the opportunity to purchase larger quantities of calves from the same cow-calf operation. Uniformity of a lot can be evaluated from various standpoints such as uniformity in breed combinations, frame, muscling, and weight (Ward et al., 2007). Having a uniform group of calves in weight is beneficial for cattle feeders because the animals will be ready for slaughter in a similar timeframe and with similar weights. A feature of online auctions is delayed delivery; buyers purchase calves ahead of time, for example they may purchase calves in September, but the delivery of the calves is arranged for November.

With live auction sales calves must be transported to the auction market by the seller prior to the sale; following the sale buyers must immediately arrange transport of the purchased calves from the auction market. At live auctions, buyers see the animals as they enter the sale ring to be auctioned off, and information provided for a lot of calves is announced by the auctioneer as the animals are selling. The online auction market allows sellers more flexibility on the price producers receive for their calves, sellers have the option to either accept or decline (pass) the final bid. For online auctions sellers do not have to transport their calves to an auction market to be sold, instead information on animal attributes as well as photos and videos are collected ahead of the sale and posted online for prospective buyers to view. Marketing calves via online auction has been shown to lower transportation costs and reduce stress known to trigger disease and weight loss (known as “shrink”) in freshly weaned calves (Rhinehart, 2011).

Private treaty marketing also known as direct marketing eliminates the need for auction services. Sellers communicate directly to buyers to arrange the sale of their animals. Direct marketing allows the buyer and seller more flexibility to create their own terms of sale. This method will have higher initial transaction costs, but lower long-term transaction costs as it can remove much of the information asymmetry. With direct marketing cow-calf producers must seek out potential buyers and promote the attributes of their cattle independently. Price discovery through auction is removed through this type of transaction. With no buyer competition there is potential for the seller to receive a lower price than if the calves were sold via auction. However, direct marketing guarantees a negotiated price and there are no marketing fees (i.e. commission)

[5] Liner load refers to the amount of weight that can be hauled on a cattle liner, used to transport cattle. Typically, the weight is 52,000 lbs (tandem axle) to 64,000 lbs (triaxle).

paid to the auction company. Direct marketing does not commingle cattle from different operations like live auction markets do, which can reduce stress and disease exposure.

2.4 Value-Added Management

"Value added" is a term referring to management practices and documentation that can create additional value and buyer demand for a commodity. Pre-conditioning, age verification, not implanting and VBP+ certification are potential ways to add value to feeder calves.

2.4.1 Pre-Conditioning

Preconditioning calves is a post-weaning management practice to prepare calves for feeding. There are many different preconditioning programs, and the term preconditioning is subjective. Some practices commonly associated with preconditioning include castration of bull calves, weaning for approximately 30-45 days prior to selling, training calves to eat from a feed bunk, dehorning if necessary, and vaccinations to prevent respiratory disease and build immunity (Wirak *et al.*, 1976; Speer *et al.*, 2001; Bulut and Lawrence, 2007). Preconditioning can add value if the buyer is willing to pay more for cattle that are claimed to be preconditioned relative to those calves where no preconditioned claim is made. Producers will profit if a buyer's willingness to pay a premium is greater than the cost of preconditioning (Speer *et al.*, 2001). Cattle feeders can increase production and efficiency of finishing calves by purchasing preconditioned calves. Preconditioned calves have shown to perform better in the feedlot with increased average daily gain, decreased mortality and morbidity compared to calves purchased from the auction market with unknown backgrounds. Despite preconditioning being a recommended practice since the late 1960s (Herrick, 1968), low adoption persists in Canada. A 2017 survey (n=262) of western Canadian cow-calf producers found only 22% preconditioned calves prior to marketing (BCRC, 2019). Preconditioning is more common in the United States; a recent survey (n=1414) found close to 75% of survey respondents were preconditioning calves (Martin *et al*., 2019).

2.4.2 Age Verification

In May 2003, the Canadian beef industry was negatively impacted by the discovery of bovine spongiform encephalopathy (BSE). BSE is a well-known challenge faced by Canadian beef producers that resulted in the industry relying on age and source verification to regain export market access. Following the BSE discovery Canadian market access was closed to 40 countries including the United States (*BSE » The Canadian Cattlemen's Association*, n.d.). During this time, Canada realized that the cattle industry relied too heavily on American slaughter capacity. The Canadian beef market was extremely dependent on exports, and with borders closed to trading partners such as Japan, U.S., and Mexico, the beef sector suffered short-run losses (Loppacher and Kerr, 2004). During the period of BSE many Canadian producers exited the cattle industry to stop financial losses as market prices fell to historic lows. During the 2000s with reduced access to international beef markets, cattle producers saw the crucial impact trade had on the industry. As markets re-opened for Canadian cattle to be traded again and BSE issues were resolved the cattle market began to strengthen.

Given BSE is most likely to develop in cattle older than 30 months of age, age restrictions to allow only cattle under 30 months of age to be exported were implemented by many countries and initially Japan would only accept beef from animals under 21 months of age (North American Meat Institute, 2016). Age verification to track and store birthdate information on cattle provided the means to identify animals under 30 months in age and helped regain access to international markets after the discovery of BSE. Age verification is part of the CCIA traceability system and information is recorded and stored in the Canadian Livestock Tracking System (CLTS) database (Canadian Cattle Identification Agency, n.d.). Although most countries have lifted export restrictions there are still 21 countries with restrictions on Canadian cattle under 30 months (Government of Canada, 2021). The adoption of age verification in Canada was largely due to the need to restore export market access following the 2003 discovery of BSE (Government of Saskatchewan, 2005). In Canada age verification of cattle is currently voluntary, but from 2009 to 2020 age verification was mandatory in the province of Alberta (Paterson, 2013).

2.4.3 Non-Implanted Beef

Some Canadian beef programs source and market beef that has been raised without the use of added hormones (non-implanted). These are additional value-added marketing channels for cow-calf producers. In September 2013 Canada's second largest hamburger fast-food chain, A&W Food Services of Canada (A&W), began sourcing beef from animals raised without growth promoting hormones (A&W, 2013). Some of the large beef suppliers for A&W are Beretta Farms, Meyer's Canada, and Spring Creek Ranch (Whelan, 2020).

2.4.4 EU Export

Canada exports beef to 62 countries around the world with the largest markets being the United States (72%), Japan (11%), China and Hong Kong (6.6%) and Mexico (3.8%) (CCA, n.d.). With 45% of annual beef production exported, Canada is continually looking to gain market share in existing markets as well as acquire new market access. There are export opportunities to the European Union (EU) for cattle that have not been implanted with growth enhancing products (GEPs). Gaining market access to the European Union was achieved in October 2016 with the signing of the Canada-European Union Comprehensive Economic and Trade Agreement (CETA) (Government of Canada, 2020a). The Canada-European Union Comprehensive Economic and Trade Agreement (CETA) was ratified in February 2017. This trade agreement provides duty-free access for 64,950 tonnes (carcass weight equivalent) (Gabruch & Micheels, 2020). There are 10 mandatory components related to identification, origin, the use of GEPs, records and verification requirements that Canadian cattle producers must follow to export beef to the EU.[6] Meeting the EU requirements requires on-farm inspection and certification by a CFIA veterinarian and rigorous record keeping which must be shared along the production chain starting with cow-calf producers. In recent years, Canada has only filled 3.1% of its annual quota (Government of Canada, 2020b). However, animals raised without growth implants or antibiotics are also sought by domestic buyers such as A&W.

2.4.5 Verified Beef Production

Verified Beef Production (VBP+) is a voluntary, market-oriented Canadian program to improve the Canadian beef value chain and to meet the growing demand for beef production systems in Canada. The VBP program was developed in 2004 and originally called "Quality Starts Here" with a focus on on-farm food safety. In 2016 the program expanded its mandate to include training and auditing of animal care, biosecurity and environmental stewardship for ranches and feedlots (*Verified Beef Production Plus*, 2021). The program works with other beef industry organizations such as the Canadian Food Inspection Agency (CFIA) and is a certification body for the Canadian Roundtable for Sustainable Beef (CRSB) certified sustainable claim. VBP+ is an audited program

[6] The 10 mandatory components are available online. https://inspection.canada.ca/exporting-food-plants-or-animals/food-exports/requirements/eu-meat-and-poultry-products/annex-r/eng/1462942544704/1462942667141?chap=2

and therefore producers (ranches and feedlots) who are enrolled in the program are held to a high standard for animal management and care as well as environmental stewardship and sustainable practices. Since 2018 VBP+ producers are also eligible for a credit (on average $18 to 20 per head) when cattle qualify according to CRSB standards and are processed at a Cargill packing plant (Home - Canadian Beef Sustainability Acceleration Pilot, n.d.). VBP+ provides transparency in beef production to consumers and retailers, giving them the confidence that animals from VBP+ operations were healthy and raised sustainably from the ranch to the feedlot. As of December 2020, there are 1,250 VBP+ certified operations (feedlots, backgrounders and cow-calf operations) in Canada, and approximately 64% of those operations are located in British Columbia, Alberta and Saskatchewan (M. Downing, personal communication August 31, 2021).

2.5 Lot Listings and Online Auctions

Three online auction companies – DLMS, TEAM and SALE – account for 85% of the feeder calf sales each fall for 2016 to 2020. Online auction companies generate electronic lot listing reports to provide relevant information about each lot on offer in a sale. These lot listing reports are used by buyers to determine which lots fit their purchasing criteria and which lots they will bid on. Each lot of calves being sold has its own entry in the report which provides a myriad of information. Examples of lot listings are shared in Appendix A. While each auction company has a different layout for their lot listing reports, the information reported for each individual lot is quite similar. The information reported for each lot includes number of animals on offer, the consignor (owner), average (base) weight of the animals, the minimum and maximum weight of the animals, location of the cattle, delivery date, percent shrink[7], price slide[8], frame, flesh[9], quality, breed, sex, colour, current diet, weigh scale location, conditions for weighing on shipping day, health program of the animals, the name of the field agent, and any additional comments about the animals.

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[7] Percent Shrink is a percentage chosen by the consigner that represents the percent of weight subtracted from the actual live weight of the cattle to determine the pay weight of the cattle. For example, if a calf weighs 750lb on date of delivery and the shrink is 4%, the pay weight will be 720lb, 750lb less 4% shrink equal to 30lb.

[8] Price Slide is a concept used when marketing cattle, sellers provide a price slide on lot listing reports to correct the price they receive for cattle if the estimated base weight differs from the actual weight of the lot at the time of delivery. It is a tool used to accommodate both the buyers and sellers to adjust the price received for a lot if animals weigh heavier or lighter than estimated.

[9] Flesh is a term used in the beef industry to describe the body condition of cattle. Light, medium and heavy fleshed are often used. A light fleshed animal has less body condition or fat than a heavy fleshed animal.

Prior to sale date online auction companies send field agents to cow-calf producers' farms to gather all the necessary information to create lot listings. At this same time the field agents may take photos and video of the calves on offer that will be posted online accompanying the lot listing. Lot listing reports are promptly removed from the auction company website after a sale concludes.

2.5.1 DLMS

Direct Livestock Marketing Systems (DLMS) provides an online auction market like that of a live auction with features such as instant bidding, streaming live video and audio for the sale. Representatives are spread out across Manitoba, Saskatchewan, and Alberta to help both commercial and purebred producers market their cattle. The DLMS feeder sale is hosted every Thursday, where cattle are listed by the DLMS agents, and introduced and sold by a live auctioneer just like a regular sale ring. Previously DLMS only included digital photos with their lot listing reports, but has recently added video of calves on offer (M.Downing, personal communication, May 27, 2021). DLMS also offers other services such as Pre-Sort Sale Broadcasts, Purebred Sale Broadcasts, Purebred Online Only Live Closeout Sales, Show/Special Event Broadcasting, and Farm Gate Timed Auctions sales.

2.5.2 TEAM

The Electronic Auction Market (TEAM) is owned and operated by The Calgary Stockyards and has been doing business since 1986. From 1986 to 2002 TEAM operated on a closed network, in August of 2002 TEAM transitioned to the Internet. Online lot listings include both digital photos and videos of calf lots on offer. All TEAM auction sales take place online and they have marketed more than four million head of cattle to date. They offer finished and feeder cattle sales, as well as specialty sales and video broadcasts. TEAM feeder cattle sales occur every Friday.

2.5.3 SALE

The Southern Alberta Livestock Exchange is an auction market located in Fort MacLeod, Alberta. SALE is also known as the Fort MacLeod Auction Market, which is a live auction market selling cattle through the ring. SALE offers a few yearling and calf online auction sales each year using DLMS' auction platform. SALE does not charge a commission to sellers in their online sale, instead a 1.5% buyer's fee is charged on all calves sold (SALE, 2020). For this research only data collected from the SALE Western Canadian Video Calf Sale will be used. This annual video calf sale takes place the second or third week in September and over the last five years (2016 to 2020) has averaged 283 lots and over 31,000 head per year.

Chapter 3. Literature Review

Hedonic modeling has been used since the 1920s to estimate the factors affecting the prices for agriculture commodities and farmland (Haas and Ezekiel, 1926; Wallace, 1926; Waugh, 1928). Since then, the hedonic pricing model has been used to estimate attribute price impacts for numerous commodities including wheat, rice, breeding animals and feeder cattle (Dalton, 2003; Dhuyvetter et al., 1996; Espinosa & Goodwin, 1991; Schroeder et al., 1988). Much of the hedonic research for North American feeder cattle has been based on the US market, with only one recent Canadian study known (Carlberg and Hogan, 2013). This chapter reviews both Canadian and US studies using hedonic modeling for feeder calves to determine the value of feeder calf attributes.

3.1 Hedonic Modelling

Hedonic modeling is used to value assets based on their attributes. Hedonic models allow prices to be estimated as a combination of implicit prices which are assigned to individual attributes of the commodity, the price of a commodity should reflect the presence and quality of its attributes (Espinosa & Goodwin, 1991). Hedonic models are used to deconstruct a given asset into individual attributes of the asset and then use ordinary least squares (OLS) regression analysis to estimate the contribution of each attribute of the asset to its overall value (Sopranzetti, 2014). A well specified hedonic model that includes many factors or attributes of the commodity can accurately estimate and explain the individual contributions of each attribute to the overall price of the asset.

Lancaster's (1966) seminal paper on characteristics is considered the first attempt at creating a theoretical foundation for hedonic modeling, where he introduced the idea of hedonic utility. Lancaster's argument is that the utility received from a good, is not necessarily due to the good itself but due to the individual characteristics that make up the good. Items can be arranged into groups based on characteristics, therefore consumers make purchasing decisions based on the number, type and quality of characteristics the good possesses (Lancaster, 1966). Lancaster's idea can be applied to the feeder calf market; all calf lots are arranged within a sale, and buyers can choose to purchase whichever lot of calves possesses the individual characteristics they are seeking. Buyers evaluate the lots on offer based on the collection of characteristics they possess and based on the level of utility each characteristic brings when buyers purchase a lot they put a value on its characteristics. Information on the characteristics of each lot of calves is found in the lot listing report.

Rosen (1974) was the first to introduce the theory of hedonic pricing. Rosen’s argument supports the idea that items can be valued by their individual characteristics, and that the total price of an item should be a sum of the price of its individual characteristics. The theory of hedonic pricing implies that an item’s price can be regressed upon the characteristics to determine how each characteristic uniquely contributes to total price (Sopranzetti, 2014). Hedonic models can be complicated by factors such as the relationship between the price and any of its characteristics that may not be linear. Multicollinearity is a concern, where model variables are highly correlated with one another (Wooldridge, 2012).

Hedonic modeling is a common choice for evaluating feeder cattle markets. A large body of research which includes Faminow and Gum (1986), Schroeder et al. (1988), Bulut and Lawrence (2007), Zimmerman et al. (2012), and Carlberg and Hogan (2013) has used the hedonic pricing model for determining the price impact of feeder cattle attributes. There are three hedonic specifications: the linear, semi-log, and the Box-Cox transformation. The linear model is commonly used in studies analyzing the value of feeder calf attributes. The linear transformation of the hedonic model used with OLS regression is suitable for analyzing the price impact of feeder cattle attributes because it allows change in price to be represented on a per hundredweight basis.

3.2 Previous Canadian Research

The only known recent Canadian study estimating price impacts associated with feeder cattle attributes was conducted by Carlberg and Hogan (2013). The empirical foundation of this research is from Bulut and Lawrence (2007) where they constructed a hedonic model for determining the value of third-party verification claims at Iowa feeder auctions. Carlberg and Hogan (2013) used data from two Alberta auction markets (Stavely and Stettler) from October 2011 to October 2012. Between the two locations approximately 79,000 head of cattle (5,800 lots) were sold; 24,000 head at Stavely (Location A) and 55,000 at Stettler (Location B). This study included 28 independent model variables for each location and 17 separate models including specific weight ranges, animal age, sale type and a pooled model with all lots. Results varied depending on the model and location. Pooled model results from all sales showed premiums for age-verified (CAD $3.93/cwt at Location

A; \$3.23/cwt at Location B) and preconditioned (\$7.79/cwt at Location A; \$5.88/cwt at Location B) animals. The model for 500 to 599 lb lots generated no premiums at Location A, for age-verification, home-raised or preconditioning, but had a CAD\$11/cwt premium for hormone-free. The Location B model for 500 to 599 lb lots estimated a \$1.08/cwt premium for age-verification, \$1.47/cwt for hormone-free, but no price impact for home-raised or preconditioned.

With only one year of data analyzed, no trends in the data can be seen. The two locations presented coefficients for attributes that had a large variation, coefficient estimates are inconsistent when comparing the two locations. This study does not portray a clear representation of feeder cattle attribute valuation in the Western Canadian beef industry over time, as it is a one-year study. This study only analyzed sales data from two of twenty-five auction marts in Alberta, there is no representation of data from other provinces or other locations in Alberta.

3.3 Previous American Research

Earlier research by Faminow and Gum (1986) focused heavily on understanding the price/weight and price/lot size relationship to provide more information on expected market behavior and assist producers in making marketing decisions. Their study included sale size, sale date, and location to summarize the price effects of these factors. Data was collected from two Arizona auction markets during the month of May for two years (1984 and 1985). There were 368 lot observations used for the analysis. The empirical model was a good fit (adjusted R-squared of 85%) and explained the variation in the dependent variables well with many statistically significant coefficient estimates. Faminow and Gum (1986) identified the optimal lot size was 60 head and that buyers are willing to pay premiums for lots that will fill a truck load. Implications of this research include, advising buyers to market calves around the optimal lot size identified, as lots that exceed the optimum and lots with 10 head or less are discounted; to consider the fundamental demand differences for steer and heifer calves; as well as encourage the industry to maintain updated market information such as what was used for this study to assist producers in making marketing decisions.

Schroeder et al. (1988) included attributes that had not yet been included in previous studies; health, presence of horns, fill appearance of cattle, lot uniformity and seasonal differences among attributes. Data was collected for spring (19 March to 15 April 1987) and fall (31 October to 13 December 1986) from seven weekly Kansas feeder cattle auction markets. Weight range for the study included calves weighing 300 to 899 lb; 17,121 lots representing 138,027 head of cattle were analyzed. For overall lots (58% steers and 42% heifers), the fall sales accounted for 57% of cattle sold and 43% of cattle were sold in the spring sales. The closing feeder cattle futures price from the most recent trading day before the auction was included as a proxy for market expectations. Steer and heifer calf lots were separated out into four categories and estimated separately, each gender had lots weighing 300 to 599 lb and 600 to 899 lb. Splitting the cattle into weight groups created a more homogeneous group for the models to capture buyers' preferences for various weight ranges. Each model explained more than 70% of the variation in feeder cattle prices. It is noted that heavier weight heifers received a premium, but they were unable to identify if heifers that received a premium were purchased for breeding stock. Valuing a premium associated with heifers purchased as breeding females has not yet been analyzed in the previous research.

King et al. (2006) observes the effect of health programs on calves sold through video auction from 1995 to 2005 to determine the value of premiums buyers are willing to pay for certified health programs in calves. This ten-year study looked at 26,502 lot observations representing 3,205,192 head of cattle, to identify the price effect of extensive health programs. For this research specific criteria were identified for each certified health program (V24, V34, V45, Viral Vaccinated, and Not Viral Vaccinated) and verified by the auction company. Producers could also enroll their calves into two additional programs offered by the auction company, the "NAT program" for natural calves and "ASV" program for age and source verified calves. Scoring systems established by the auction service were used to collect information for flesh, frame, and amount of variation in weight of a lot. Over the time of the study data showed the percent of calves not viral vaccinated progressively decreased. In 1995, 44.7% of calves were not viral vaccinated, but by 2005 the proportion had decreased to 3.9% of lots. Price premiums for the V45 calves were the highest and ranged from USD$2.47 to $7.91 per cwt, this is likely due to the extra booster vaccinations and the 45-day weaning period prior to sale required for the V45 program.

Bulut and Lawrence (2007) focused on the value of third-party certification for preconditioning at Iowa auction markets using a hedonic pricing model and OLS regression. The objectives of this paper were to identify if the higher cost of third-party certification of preconditioning is offset by a higher premium paid, and to identify if the market can distinguish the value between uncertified and third-party certification claims. This study included 19,046 lots of feeder calves (300 to 900lb) sold in various Iowa sale barns from October 2005 to February 2006. The model was estimated to explain 70% of the variation in price for feeder calves. Thirty-seven percent of lots had third-party certification claims for preconditioning and 57% of lots had uncertified or incomplete preconditioning claims. Third-party certification programs can decrease information asymmetry between buyers and sellers, allowing buyers to trust and value information from the seller when making feeder cattle purchases. Third party certification provides buyers with confidence in unobservable claims made by a seller such as management practices and vaccination. A premium of USD$6.12 per cwt was estimated for calves with third-party certification, compared to $3.35 per cwt for uncertified preconditioning claims.

Blank et al. (2009) studied video auction data for both steers and heifers with the objective of determining the price difference for calves sold in the west compared to the Midwest US and to identify price effects of value-added attributes. This study analyzed both yearling and calf lots, but this review will only focus on results from the calf models. There were 4,116 steer calf (500 to 625 lb) lots representing 571,000 head sold through video auction from 1997 to 2007. Most of the feedlots and processing plants are in the Midwest, therefore cattle sold in the west are discounted due to additional costs associated with transportation of the cattle as well as supply and demand changes. This research provided valuable information for the US beef industry on the price effects of the location where the cattle are sold, and how proximity to the major feedlots and processing plants significantly effects the prices paid for feeder calves. Blank et al. (2009) used annual regression models and found variability in the significance of the value-added variables depending on the year. That is a representation of the volatility in cattle markets and how attribute values vary overtime; it is not uncommon to have variability in the significance of coefficient estimates for the same attribute over different years.

Schulz et al. (2010) focused on factors affecting feeder cattle prices in Kansas and Missouri. Their objective was to update information from previous literature for producers to have current information of how premiums and discounts offered for attributes has changed over time. Cattle markets are dynamic and the preferences of buyers and their willingness to pay has shown to change overtime. This study included data from live auction markets with 8,200 lots (84,319 head) in the analysis. Calves weighing 300 to 900 lb were included in the study; 48% of lots were steers, 42% heifers and 10% bulls. Like much of the existing research, the hedonic pricing model was used to evaluate the price effect of calf attributes. One difference of this study compared to previous is only one model was used to evaluate all lots. Many factors influencing sale price were included in this study such as, lot size, weight, frame, muscling, uniformity, breed, and colour. The results of these specific factors will be further discussed in the following section.

Zimmerman (2010) used a hedonic pricing model with OLS regression to estimate price determinants for feeder calves in the US from 1995 to 2009 using Superior Livestock Auction (SLA) video auction data. SLA is the largest video auction in the United States. SLA auction market data is routinely collected from lot listing reports and compiled into a database for research use by Pfizer Animal Health. One of the main objectives for this study was to capture the long-run evolution of SLA and the vertical coordination of the cow-calf sector. Both traditional feeder calf attributes and value-added attributes such as natural market eligibility and Non-Hormone Treated cattle programs were included as model variables as these programs were implemented over the timeframe of the research. Data was collected on 20 to 25 annual feeder calf sales from June to September, the number of calves marketed through SLA video auction grew substantially in the first ten years. The data included 53,612 lots of calves (31,655 steer lots and 31,655 heifer lots) ranging from 450 to 750lb for steers and 400 to 700lb for heifers.

Seeger et al. (2011) analyzed the price effect of management, marketing and certified health programs on calves sold through video auction from 1995 to 2009. Data for 41,657 lots representing 5,042,272 head of beef cattle was collected using sale catalogue listings (lot listing reports). This study included variables for various programs offered in the US at the time such as, BVD-PI free program, non-hormone treated cattle program, progressive genetic program, natural program, age and source verification and other certified health vaccination programs. The weight range of calves for the study was 320 to 900lb and steer and heifer lots were separately analyzed using a multiple regression model. It is stated that sex of the calf, weight, lot size, health of calves, and the presence of horns all significantly influence calf prices regardless of the type of auction (i.e., video sale or live auction). This is important to note as the objectives of this research can be also applied to live auction markets, and that the market dynamics are similar over the various marketing platforms.

Zimmerman et al. (2012) analyzed over 33,000 lots (~ 4 million head) from 2001 to 2010 sold through SLA. The model used was the first multi-year study to separate out the marginal values associated with bundled practices (vaccination, implanting, weaning, etc.). The study used separate models for steers and heifers to analyze price differentials of 17 traditional and value-added attributes. Feeder calf lots sold during the months of June through to September were used, and a weight range of 450 to 750lb for steers and 400 to 700lb for heifers were included. A hedonic pricing model with OLS regression was used to estimate yearly models for both steers and heifers over the ten-year timeframe. Yearly models were used to identify trends over the timeframe of the price effect of attributes. This study is one of few studies that include days to delivery, and results were statistically significant. A large focus of Zimmerman et al. (2012) was the different verified vaccination programs offered by SLA and what price effects were associated with various health attributes.

McCabe (2018) analyzed video auction market data for calves sold through SLA from 1995 to 2016 to determine the price effects of various attributes with a specific focus on breed. This study included two model results, the first being 1995 to 2016, and the second, 2010 to 2016. The 2010 to 2016 model will be used when discussing this research and reporting results. The US was separated into five regions for the analysis (Rocky Mountain/North Central, West Coast, South Central, Northeast, Southeast) to determine if breed preferences for calves differ throughout the different production areas of the US. Breed composition of calves was a focus for this research, and lots were categorized into one of six breed groups (English and English-crossed, English, and Continental-crossed, Black Angus-sired out of dams with no Brahman influence, Red Angus-sired out of dams with no Brahman influence, Charolais-sired out of dams with no Brahman influence, and Brahman influenced). Steer and heifer models were evaluated separately using a multiple regression model. Overall, 29,103 steer calf lots and 18,955 heifer calf lots were used in the analysis. This research found significant premiums for the various breed compositions for US feeder cattle.

3.4 Factors Influencing Sale Price

Factors such as weather and market prices are out of the control of producers. Producers do have the ability to determine input costs and calculate a breakeven sale price for their calves. Producers have control over factors such as the marketing venue, time of year to sell their calves, health programs, body weight and condition of the calves (Schroeder et al., 1988; Ward et al., 2007). Producers can try to differentiate their calves from others to gain a competitive advantage by offering calves with attributes that buyers value. When buyers are determining how much they are willing to pay for each calf lot, they take into consideration the lot listing description factors and the average market prices at the time of the sale. Many of the calves' physical characteristics can be seen through the photos and videos of each lot, but other claims such as health programs, weaning status, feed and mineral programs cannot be visually observed by buyers (Bulut and Lawrence, 2007). Buyers have a higher willingness to pay for calves that they think will perform better in the feedlot and packer stage of production. Specifically, calves that have a high feed conversion ratio are more desirable because they will consume less feed and reach slaughter weight quicker (Schulz et al., 2010). Beef packers desire cattle that have high carcass yield, and good meat quality. Packers assess meat quality by attributes such as muscling, marbling, and fat colour/texture. Many meat quality attributes are influenced by breed, genetics and management practices, producers have control over these factors.

Producers respond to market signals and adopt new practices that are valued and expected by buyers. Over time buyers' preferences change as well as their willingness to pay for certain attributes. For example, King et al. (2006) state that at one time few producers administered pre-wean vaccinations and therefore buyers were willing to pay premiums for calves vaccinated against respiratory disease. As pre-weaning vaccinations have become a common practice for producers, premiums have diminished.

3.4.1 Calf Sex

Most of the current literature analyzes steer and heifer calf lots in separate models. Schroeder et al. (1988) was the first study to use separate models for steers and heifers. Various studies have shown steer calves yield higher prices than heifer calves on the market. Steer calves are ideal for feeding and finishing because they have better feed efficiency, grow faster and can be fed to heavier weights compared to heifers (Zimmerman, 2010). Unlike steers, heifers pose a potential for additional management problems when being fed such as, unplanned pregnancy, lower feed efficiency, and estrous cycles (Stewart, 2013). As the cattle cycle moves through its different stages the demand for and prices of heifers fluctuate. During the liquidation stage few producers are retaining heifers to expand their breeding herd, resulting in larger volumes of heifers available for sale which drives the price down. During the expansion stage of the cattle cycle many producers will retain replacement quality heifers, and only offer “second cut” heifers for sale.[10]. As a result, heifers sell at discounted prices relative to steer calves. Schroeder et al. (1988) found that heavier weight heifers received premiums, as they were suspected to be purchased for breeding stock. Although some studies have discussed the potential that higher quality, heavier weight heifers may be receiving premiums due to potential for breeding stock, no current research has been able to fully understand or explain the price premiums associated with replacement quality heifers.

3.4.2 Base Weight and Weight Variation

All online lot listing reports include the base (average) weight of a lot of calves being sold. Base weight has been incorporated in the majority of the previous literature; it has been used to classify calves into weight ranges for separate models and included as an independent variable to measure the price effect of a 1-pound increase to the base weight of a lot. The relationship between weight and price received for feeder cattle has been thoroughly analyzed in the existing literature. Results support that the coefficient sign for base weight is negative in most models, that as the weight of a lot increases buyers are willing to pay less per pound for the lot.

Faminow and Gum (1986) focused on explaining the non-linear relationship between price/weight. Their model is non-linear in terms of weight and lot size and includes squared terms for both variables to account for the nonlinearities in the model. Results found that the price/weight relationship differs for steers versus heifers, steers often have a convex price/weight line where heifers usually have a slightly concave price/weight line. This is suggested to be due to the fundamental different demands for heifers versus steers, as heifers may be purchased for replacement breeding purposes. They found that at 615lb for heifers the value/weight line is concave and becomes negative, this suggests that marketing heavier weight heifers would decrease the total value of the animal. It is important to note that this research was done 35 years ago, how the market values feeder cattle weight has evolved, but the foundational ideas applied such as the non-linear price/weight relationship are still relevant today.

Schroeder et al. (1988) included base weight as an independent variable as well as separate models by weight range. They used two weight ranges (300-599lb and 600-899lb) for both steer

[10] The term “second cut” is commonly used in the beef industry to describe heifers of lower quality compared to replacement-type heifers. The second cut are the heifers left after the replacement quality heifers have been retained for herd expansion.

and heifer models. Having a tighter weight range allows each model to evaluate the price effects for lighter vs heavier weight calves, as management and objectives for purchasing calves in different weight ranges varies. Results found that price declined as weight increased for all models, except the heavier weight heifers. The price discount for a 1-pound increase in base weight ranged from USD$0.0716 to $0.412 per cwt, but for heifers in the 600 to 899lb model price increased $0.577 per cwt as base weight increased by 1-pound. The results of heavier weight heifers receiving a premium indicates they may be purchased for breeding stock. This study also reported that seasonality affected calf prices, and that the discount for additional weight is less in the fall than in the spring. Lot uniformity was included in the model as an independent binary variable. Lot uniformity was only significant in the steer models and resulted in a discount ranging from $0.328 per cwt to $0.583 per cwt for non-uniform lots.

Like many of the other studies Blank et al. (2009) found that calf lots were discounted USD$0.68 per cwt for every 1-pound increase in base weight. This study also included an independent variable for weight variability of cattle in the lot and found a $0.88 per cwt discount for lots with more variability.

Similar results to those found in Schroeder et al. (1988) were found in Schulz et al. (2010) that a price discount for heifers compared to steers occurs, but for heavier weight heifers the discount narrows compared to light weight heifers. This may also provide results supporting that heavier weight heifers are more valuable than lighter weight heifers due to increased replacement potential. This study included weight uniformity as a model variable and found a significant discount of USD$2.11 per cwt for non-uniform lots of calves.

Zimmerman (2010) included separate models for steer and heifer calves. The steer calf model used a weight range of 450 to 750lb with a mean base weight of 583lb, and a weight range of 400 to 700lb for heifers with a mean base weight of 544lb. They found in the 2008 to 2009 models that the average base weight variable had a price discount USD$0.3825 per cwt for steers and $0.3130 per cwt for heifers. This result is consistent with other studies due to the non-linear relationship between price and weight. A weight variation or uniformity variable was included to estimate the price effect of even to fairly-even, uneven and very uneven lots. Lots that were even to fairly-even received premiums for both steers and heifers when compared to the base of uneven, premiums were $0.5293 per cwt for steers and $1.352 per cwt for heifer calves.

Zimmerman et al. (2012) found that weight had a non-linear impact on price, and for example in the 2010 models a 500lb steer brought about USD$9 per cwt more than a 600lb animal. For heifers a 500lb calf brought $6.70 per cwt more than a 600lb calf. This study included a categorical variable for weight variation/uniformity and found that discounts for lots with very uneven weight variation ranged from $1 to $3 per cwt depending on the year and gender of the lot.

3.4.3 Lot Size

Lot size refers to the number of animals for sale as one group or lot. Usually, the animals in a lot will be of the same sex and weight increment. Lot size for animals sold via online auction as well as live auctions can vary considerably. Figure 3.1 shows average lot size per year for steers and heifers, weighing 400 to 800lb sold via online auction in Western Canada from 2016 to 2020. It is common for larger producers to divide their calves into more uniform weight groups and have separate listings based on those weight groups when selling online. By doing this a seller can provide buyers with a uniform package of calves with similar weight ranges that will perform well in the feedlot together. Live auctions often combine calves from multiple producers to make more uniform lots. Studies have shown that when producers have enough calves in a lot to fill a cattle liner a premium is paid compared to smaller lot sizes (Bulut & Lawrence, 2007; Schulz *et al.*, 2010; Seeger *et al.*, 2011; Zimmerman, 2010). When the number of head in a lot exceeds what can fit on one truck-load prices begin to decrease, likely due to fewer buyers for larger lot sizes or transportation inconvenience and costs (Schulz *et al.*, 2010). Lot size can relate back to the concern of increased health risks when commingling different sources of cattle, when lot sizes are less than or greater than one truck-load a buyer may have to mix different groups of calves together to make a full truck-load. Transportation costs for a single lot increase if the lot size is less than a truck-load, the cost of transportation per head increases, which will likely decrease a buyer's willingness to pay for less than a full truck-load of calves (McCabe, 2018). It is also important to note that buyers are often large feedlots that need 250 to 300 head per pen, and therefore larger lots of uniform calves are appealing to fill pens with calves from a single ranching operation.

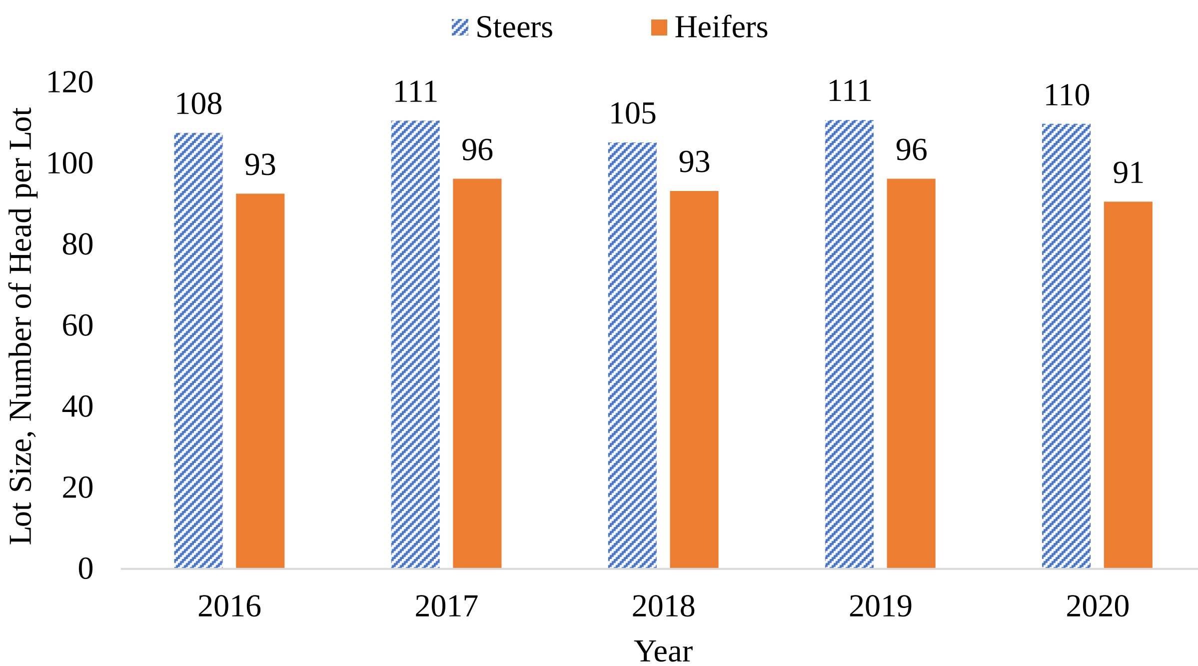

Figure 3-1. Average Lot Size per Year for Steers and Heifers, 2016 to 2020

Faminow and Gum (1986) identified maximum prices paid for calves marketed in 60 head lot sizes. Bulut and Lawrence (2007) found that as lot size increased, price increased reaching a maximum premium at 77 head. Seeger et al. (2011) had a mean lot size of 121 head (range, 116 to 128 calves) over the 15 years of the study and a slight premium was paid for a 1-calf increase in lot size, USD$0.0035 per cwt in 1995 and $0.0179 per cwt in 2004 (data used was centered to the mean). Bailey and Peterson (1991) estimated an optimal lot size of 240 head. Zimmerman (2010) found average lot size to be 120 to 125 head for the SLA video auction data, premiums paid for a 1-calf increase in lot sizes for steer calves ranged from USD $0.0089 per cwt in 2008 to $0.0235 per cwt in 2004 and an optimal lot size of 575 head. Schulz et al. (2015) found the optimal lot size for regular auctions to be 130 head, but for preconditioned sales the optimal lot size was 24 head. It is important to note that the more recent studies have a higher optimal lot size than earlier research such as Faminow and Gum (1986).

3.4.4 Frame Size and Fleshiness

Frame size and fleshiness are both subjective descriptive attributes that are included for each lot sold via online auction and are determined by the auction company agent listing the cattle. They are considered subjective because they are a visual attribute that may be evaluated or observed differently by each individual.

Frame size descriptors are often small, medium and large framed. When a field agent visits an operation to view calves being consigned for a sale they will estimate what percentage of the animals in each lot are small, medium or large framed. Buyers use frame size as an indicator of how the cattle will feed and finish, and to forecast the growth pattern of the calves (McCabe, 2018). Zimmerman et al. (2012) found that small-framed calves received discounts in the market of USD$0.25 to $0.77 per cwt compared to medium-framed calves. The results of this study yielded considerably lower discounts for small-framed cattle than other studies. A study by Schulz et al. (2010) looking at feeder cattle sold in a sale barn in Missouri and Kansas found larger discounts for smaller-framed cattle. Small-framed calves were discounted $5.98 per cwt compared to the base model (medium-frame) while large-frame calves received a premium of $0.75 per cwt. In a 15-year study by Seeger et al. (2011) frame size had a significant effect on price in seven years of the study (1996, 2001, 2003, 2004, 2006, 2007 and 2008), with large-framed calves selling for a higher price than small-framed calves. Cattle feeders and packers view larger-framed calves as superior for feeding and processing, respectively, due to their growth pattern and finishing weight. Smaller-framed calves can be discounted due to uncertainty of how the calves will finish and if the animal will meet packer expectations for carcass size and quality (Seeger et al., 2011). Overall significance and coefficient estimates for premiums and discounts associated with frame size vary.

Fleshiness refers to the weight condition of an animal, animals that are considered fleshy typically have more body fat or condition. Fleshiness is often described as light, medium or heavy flesh, or a combination. Fleshy cattle are often discounted in the market, because having more body condition before starting on feed can decrease potential gain for the buyers (Bulut & Lawrence, 2007). Bulut and Lawrence (2007) estimated fleshy cattle to be discounted USD $2.37 per cwt, compared to not fleshy calves. Seeger et al. (2011) used flesh scores from the auction market representatives and found varying coefficient signs for fleshiness over the nine years the variable was included, and some years flesh score was insignificant. Zimmerman (2010) used four categories to classify fleshiness (light to light-medium, light-medium to medium mix, medium and medium to medium-heavy mix to heavy), results varied by year and gender of the lots. The base was medium flesh, and from 2004 to 2009 light-medium to medium mix steer calves received premiums ranging from USD $0.90 to $2.25 per cwt compared to medium flesh calves. Discounts of $1.36 to $1.78 per cwt were given to medium to medium-heavy and heavy fleshed steer calves in 2005 to 2007. The heifer models presented similar results, but the premium received for heifers with light-medium to medium mix flesh were lower than for steers, $1.18 to $1.44 per cwt in 2005 and 2006, respectively.

3.4.5 Breed and Hide Colour

Much of the previous US literature includes Brahman influenced cattle, but in Canada the Brahman breed is uncommon. In the US Brahman influenced cattle are more popular because they perform well in hot and dry climates. Brahman cattle are not practical for colder Canadian climates, and therefore Brahman cattle are not a popular breed in Canada. The various research categorizes cattle breed differently, but it is known that breed has a large impact on prices received at the auction market for feeder calves (McCabe, 2018; Schulz et al., 2015; Zimmerman, 2010; Zimmerman et al., 2012). Each breed of cattle is known for different traits and characteristics; cattle buyers use breed to predict how cattle will grow and perform in the feedlot. Table 3.1 supports that hide colour of cattle can be associated with breed (Rolf, 2017).

In Canada there are both English (British) and Continental (Exotic) breeds. Angus is an English breed known for maternal instinct and increased carcass quality with high marbling beef. Consumers often associate the Angus breed with a high quality of beef, which is why beef is labeled as “Angus” in restaurant menus and grocery store labeling. Continental breeds, such as Simmental and Charolais are typically known for their high yield of meat, efficient growth rates and larger body types (Canadian Beef Breeds Council, 2021).

Table 3-1. Hide Colours of Common Cattle Breeds

Black Only	Red Only	Black and Red	White or Cream	Mixed Colours and/or Roan
Black Angus	Red Angus	Gelbvieh	Charolais	Longhorn
Chiangus	Hereford	Limousin		Maine-Anjou
		Simmental		Shorthorn
		Salers		
		SimmAngus		

Adapted from Rolf (2017)

Breed trends change over time and buyers' preferences shift depending on many factors of beef cattle production. In Canada in 2019 there were a total of 118,816 head of beef cattle registered with a breed association. Figure 3.3 shows the percentage of registered animals for seven of the most popular breeds in Canada. The top four breeds of registered cattle are Angus (47%), Simmental (19%), Charolais (12%) and Hereford (10%) (AAFC, 2021). Commercial producers source bulls for breeding stock from purebred breeders, the number of registered cattle in each breed is an indicator of the most popular breeds of cattle used by commercial cow-calf producers (Canadian Beef Breeds Council, 2021) (*History of Purebred Cattle in Canada | Canadian Beef Breeds Council*, 2021). Commercial producers often use crossbreeding within their programs, but the main herd sires are selected from registered purebred breeders.

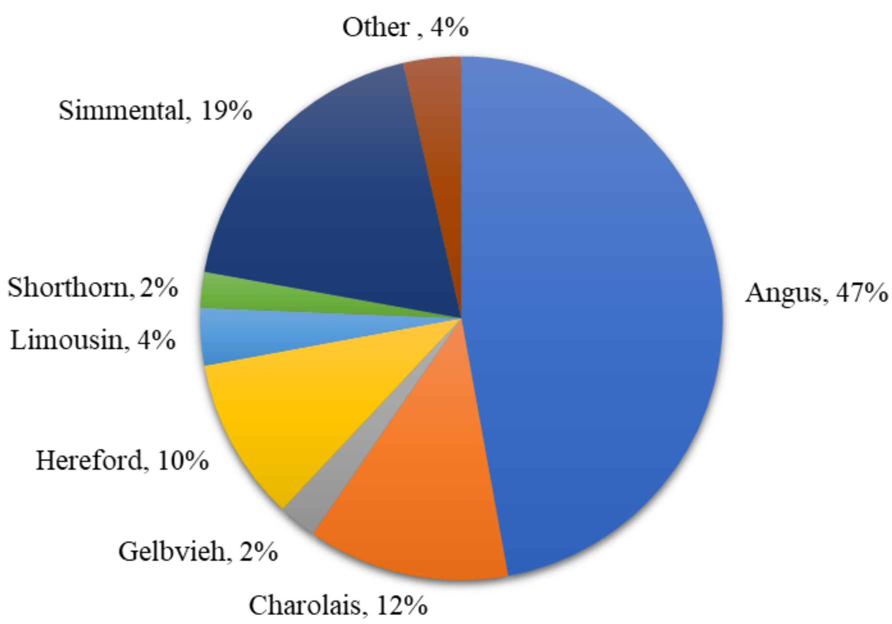

Figure 3-2. Percent of Total Beef Registrations, in Canada
Source: AAFC (2021)

Zimmerman (2010) found that from 2004 to 2009, cow-calf producers were transitioning from non-black English-Continental and Brahman influenced cow herds to Angus and black-hided breeding programs. Brahman influenced calves were the base breed used in the study; they found the highest premiums were for Angus and black-white faced calves, and ranged from USD$4.15 to $8.20 per cwt. Continental influenced calves received the smallest premiums compared to Brahman calves, with premiums ranging from $1.20 to $5.05 per cwt.

Zimmerman et al. (2012) used six breed categories: 1) Brahman and Brahman cross, 2) English and English cross, 3) Continental and Continental cross, 4) English-Continental cross, 5) black or black-white faced, and 6) predominately black Angus. Lots that were classified as predominately black Angus required a written description of Angus breeding stock in the lot description and 90% of the lot was black or black-white faced. In this study Angus, black or black-white face calves consistently received a premium of a USD$3 to $7 per cwt when compared to the base Brahman-influenced calves. Over 10 years, predominately black steer calves received an average premium of $5.30 per cwt and heifer calves a premium of $5.75 per cwt. Larger premiums for heifer calves may be the result of calves being purchased as replacement quality heifers where buyers were willing to pay premiums for good quality breeding stock.

Canadian research by Carlberg and Hogan (2013) provided inconclusive results on the influence of breed and hide colour on price. At Location A, British breed calf lots brought premiums of CAD $3.10 per cwt and at Location B there was no effect. Further research will be needed to provide insight on how breed influences calf prices in Canada. This study also included a variable for black hided animals, at Location A there was no effect on price, but at Location B black hided animals were discounted $2.84 per cwt.

Schulz et al. (2015) used hide colour as a proxy for breed, as buyers at the auction market often associate hide colour with specific breeds. They found all coat colours received a discount compared to black animals, at the 10% significance level yellow/white calves were discounted USD$2.67 per cwt and red and white animals were discounted $4.49 per cwt. They stated that producers often associate black hided cattle with the Angus breed. Bulut and Lawrence (2007) also found premiums associated with black hided cattle when compared to nonblack cattle, the premium received for black cattle was USD$3.34 per cwt. As the frequency of black animals in the lot increased the price also increased.

McCabe (2018) focused heavily on how breed influence affects the price of feeder calves. Calves were classified into one of six breed categories: English and English-crossed with no Brahman influence, English and Continental-crossed with no Brahman influence, Black Angus sired out of dams with no Brahman influence, Red Angus sired out of dams with no Brahman influence. Lots of Charolais sired and Red Angus sired steers calves brought the highest sale prices when compared to other breed categories at $179.09 and $177.86 per cwt, respectively. The highest sale prices were paid for Red Angus sired heifer calves when compared to all other breeds at $173.88 per cwt. The study concluded that value placed on breed composition varies for steers and heifers depending on the purchasing intent of the buyers.

3.4.6 Location and Year

Each study defined the location of where the calves for sale originate from, as well as a timeframe that data is collected over. Location is a factor affecting the price of feeder calves, but it is hard to compare results from various locations as the markets for each area are complex and specific. The previous research does however support the idea that location of origin (where the calves for sale are located) does affect the price received for feeder calves. Much of the existing research has been done in the US and therefore the specific effect of the location variable cannot be compared to this Canadian study for feeder calves. The various studies over different timeframes allow market events or trends to be observed. Faminow and Gum (1986) analyzed Arizona auction markets from 1984 to 1985, Schroeder et al. (1988) analyzed Kansas feeder cattle auction data from 1986 to 1987, Bulut and Lawrence (2007) analyzed data from 2005 to 2006 and Schulz et al. (2015) analyzed Iowa feeder cattle auction data from 2008 to 2014. In the US, Blank et al. (2009) focused on the price effect of multiple different regions in the US using video sale data. Their results support the hypothesis that calves that originate further from the Midwest feedlot area are discounted.

Online or video auction data is commonly used in feeder calf price determinants, such as in Zimmerman (2010), Zimmerman et al. (2012) and McCabe (2018) using SLA video sale data. The Canadian study by Carlberg and Hogan (2013) used live auction data from two Alberta auction markets over a one-year period (2011-2012). The addition of this research to the Canadian literature will provide more information on how different provinces of origin in Western Canadian feeder calf sales affect calf prices.

3.4.7 Cattle Futures

Cattle futures have been included as an independent variable in feeder cattle hedonic models since Schroeder et al. (1988). However, studies incorporate futures prices differently — nearby versus distant contracts, feeder versus live cattle. Bulut and Lawrence (2007) and Schroeder and Dhuyvetter (2000) both used the live cattle futures closing price from the Chicago Mercantile

Exchange (CME) for the month the feeders were expected to be marketed. If a lot was between 300-499 lb, the fifth distant live cattle futures close was used. If the lot averaged 500-699 lb, the closing price for the fourth distant contract was used. If the average weight of the lot was between 700-900 lb, the second distant contract was used.

Schroeder and Dhuyvetter (2000) provide insight into how the price-weight relationship is affected based on feeder cattle futures prices, the price of corn and the interactions that occur. They found that price weight spreads are seasonal and influenced by the corn prices and feeder cattle prices. For example, the price spread between 500 and 800lb steers is more than USD$20 per cwt when corn price is lower at $1.68 per bushel and declines to about $7 per cwt when corn prices increase to $3.52 per bushel. The price buyers are willing to pay for feeder cattle is influenced by the live cattle futures; when the futures price increases the demand for light weight calves is expected to increase because light weight cattle will gain faster and are now higher in value.

Zimmerman (2010) used feeder cattle futures closing price from the day before each SLA sale for the nearby contract pertaining to delivery date of the lot. This study did not include corn prices because including feeder cattle futures prices and corn futures caused potential collinearity issues and it was concluded that the corn futures prices was reflected in the feeder cattle futures price already. Results estimated a positive coefficient sign for feeder cattle futures prices for Zimmerman (2010) and Schroeder and Dhuyvetter (2000).

The Canadian study, Carlberg and Hogan (2013), used CME futures closing price for the nearby live (fed) cattle futures for the day of the sale. One location showed no effect on price for futures prices and the other had CAD $0.34 per cwt for every $1.00 increase in the cattle futures price. However, CME futures trade in US currency and are based on local market conditions. Changes in the currency and basis should also be considered.

3.4.8 Age and Source Verification

In the majority of the current literature, age and source verification have had a positive effect on cattle prices, suggesting buyers value calves that are age and source verified. Having this information allows buyers to make more informed bidding decisions on age. Some western Canadian lot listing reports (TEAM and DLMS for all five years, and SALE 2018-2020) have a yes or no check box for age verified calves and if the lot includes the birth date or month of the calves it is noted in the comment section or within the check box.

Lawrence and Yeboah (2002) provided one of the first studies to value age and source verification (ASV) for feeder calf auctions. This study used Iowa auction data, but the model did not include many of the traditional attributes such as breed, weight variation, frame or flesh that have been used in many of the previous studies. Results for lightweight calves showed a premium of USD $1.30 per cwt for ASV calves. It was estimated that the number of head and the uniformity of the lot also mattered to the premiums received for ASV calves. Kellom et al. (2008) used 2007 Montana feeder calf data from SLA, to develop a hedonic model using OLS regression to estimate the value of ASV, weaning, sex and seasonal differences between June and July sales. They found the value of ASV to be USD $2.13 per cwt for Montana feeder calves. Blank et al. (2009) included ASV in the 1997 to 2007 study where they found a large premium of USD $5.31 per cwt for ASV calves. Zimmerman (2010) found premiums of USD $1.58 per cwt for steer calves in the 2008 to 2009 model, and a premium of $1.66 per cwt for heifer calves. Seeger et al. (2011) analyzed ASV as a factor influencing sale price from 2005 to 2009. Results from this study found buyers paid more for ASV calves, with premiums ranging from USD $0.52 to $2.14 per cwt. ASV was a variable in the 2005-2010 models in Zimmerman et al. (2012). For calves to be ASV they must have an RFID identification tag and producers must pay an enrollment fee; ASV calves have additional export market opportunities (Zimmerman et al., 2012). During the five years ASV was included in models premiums ranged from USD $0.99 to $1.94 per cwt for steers and $1.09 to $2.75 per cwt for heifers. Overall results from this study supported that ASV is profitable for producers. In the Canadian study by Carlberg and Hogan (2013) there was no effect on price paid for calves announced as age verified for Location A, and Location B received a premium of CAD $1.62 per cwt for age verification in the 'calf age' model.

3.4.9 Implant Status

One of the important management decisions faced by producers is whether to implant calves with GEPs. According to the 2017 Western Canadian Cow-Calf Survey, 26.5% of cow-calf producers surveyed are implanting suckling calves (University of Saskatchewan, 2018). In the US the percentage of herds utilizing implants prior to weaning increases with herd size; as of 2017 8.4% of all beef cattle operations use implants, but for herds with 200 or more beef cows 31.4% of operations are implanting calves (USDA, 2020). Growth implants were first approved for beef cattle in the 1950s (Raun and Preston, 1997). An implant is a small pellet inserted under the skin on the backside of an animal's ear. The pellet slowly releases hormones into the animal's bloodstream over a period of time, then a biological response is triggered within the animal's body (*Manitoba Agriculture*, n.d). Implanting calves is shown to enhance production efficiency, reduce the cost of production and improve profitability of the animal (Reinhardt, 2007). There have been hundreds of research trials involving implanting beef cattle, with positive results that implanting calves returns more revenue per dollar invested than any other management practice (Stewart, 2013). A review by Selk (1997) concluded that implanting suckling beef calves increased average daily gain (ADG) in steer calves by 0.10lb/day and 0.12 to 0.14lb/day in heifers, from the time of implanting to weaning.

There are several implants on the market available to producers, choosing the correct implant and proper administration is essential for success. In some cases, implanting nursing calves twice improves the average daily gain of the calf compared to only one implant. Research shows calves with better nutrition have a greater response when implanted. During the finishing phase growth responses to implants are the highest. With a combination of estrogen/androgen implants, calves can see a four to five percent increase in feed efficiency (Stewart, 2013). This is one of the reasons feedlots implant calves upon arrival to maximize ADG when calves are started on feeding rations.

Carlberg and Hogan (2013) included "hormone free" (non-implanted) as an independent variable in their models, if the auctioneer announced cattle were raised without added hormones the lot was designated as hormone free. Results from both locations for the calf model showed no price effect for calves announced as hormone free.

Zimmerman et al. (2012) accounted for five variables involving implants: not implanted, Natural Eligible – not implanted, Non-Hormone Treated Cattle (NHTC) – not implanted, unknown or some implanted, and implanted. Natural and NHTC are value-added programs offered by SLA, they are third-party verified and require a signed affidavit from sellers. In 2004 SLA started the Certified Natural Cattle Program and the NHTC program in 2008 (SLA, n.d.). Results from Zimmerman et al. (2012) regarding non-implanted premiums varied by year with no clear pattern found. In 2006, premiums for natural-market eligible calves were USD$0.81 per cwt for steers and $1.09 per cwt for heifers. In 2008, natural market eligible heifer calves received a premium of

$0.73 per cwt, with no other years having statistically significant premiums for natural-market eligible calves. Results of this study showed overall that implanted calves did not receive a discount in the market and producers who implanted their calves did not receive lower prices in comparison to calves that were not implanted. However, calves that were listed as having an unknown implant status were discounted, discounts ranged from $1.59 to $2.19 per cwt for steer calves. Zimmerman et al. (2012) suggests that results support the idea that implanted calves have increased efficiency and performance and therefore implanting calves could increase profitability for producers.

Implanting heifer calves can be a controversial topic within the beef industry. Although there are implants approved to be used in replacement heifers, many producers are reluctant to implant heifers due to potential negative effects on reproduction. Selk (1997) evaluated the effect implanting heifer calves has on reproduction, it was found that if heifers are implanted only once between one and three months in age, that pregnancy rates were only slightly lower than that of non-implanted heifers. However, in trials where heifers were implanted twice, pregnancy was reduced by 7.3% compared to non-implanted heifers. It is essential for producers to read and fully understand the label for implants used on heifers. There have been several studies conducted on pregnancy rates of implanted and non-implanted heifers and some studies have shown a significant reduction in pregnancy rates in implanted heifers (Mathis, 2010). If producers can identify which heifers will be replacement quality or if they are wanting to retain some heifers as replacements early, then those heifers should not be implanted. Research shows there is little advantage to implanting replacement heifers, and only those heifers intended for feeding and finishing should receive implants to benefit from the added weight gain (Stewart, 2013).

3.4.10 EU Export Eligibility

There are additional domestic and export opportunities for cattle that have not been implanted with growth enhancing products (GEPs), this is one of the main reasons it is important for cow-calf producers to report implant status of calves on lot listing reports. The CETA trade agreement opened Canadian market access to the EU. The current literature does not include a variable for EU certification and therefore no prior information is available on the specific effect EU certification will have on calf prices. However, Carlberg and Hogan (2013) do include a hormone free independent variable in their model that may be used as a proxy for non-implanted or EU eligible cattle, but they found no price effect on calves that were announced as hormone free.

In Gabruch and Micheels (2020) Canadian study, they utilized a systems dynamics approach to estimate the economic impact that meeting EU standards has on cow-calf producers. Like most value-added programs there are additional implementation costs for producers to be compliant with EU beef productions standards. This study found for producers that had current management practices closer to the EU standards the associated costs were less, compared to producers that were less compliant with their current management practices. For a producer who already does not use GEPs and maintains a management identification system the additional costs for the EU market were estimated at CAD $2.13 per calf. But, for a producer that uses GEPs and does not have identification protocols in place the additional cost is much larger at $34.78 per calf. This study also estimated the premium that would need to be received for cow-calf producers to break-even implementing EU beef production regulations. The two scenarios identified as having the largest percent of calves are scenario D (70.68%) which are producers that are most compliant with EU standards, only needing to undergo CFIA inspection and documentation and scenario B (22.32%) producers who have an ID system in place, but also implant calves. For scenario D producers would need a small premium of CAD $0.0039 per cwt to break-even implementing the EU protocols, and for producers in scenario B the premium needed would be $0.0534 per cwt. These estimated break-even premiums can be compared to results from this study to provide insight for cow-calf producers if having EU certified calves is a profitable management decision.

3.4.11 Weaning and Vaccination Status

Much of the existing research looks at weaning, preconditioning and vaccination status of feeder calves. Each study has a bit of a different definition for weaning, preconditioning and the various vaccination programs. Previous US literature has focused heavily around identifying the value of various weaning/preconditioning, and vaccination programs.

Roeber and Umberger (2002) estimated the value added to cattle feeders by purchasing preconditioned calves is USD $46.83 per head, with this added value cattle feeders can afford to pay a premium for preconditioned calves. Blank et al. (2006) analyzed US video auction data from 1997 through 2003. In this study preconditioned calves were defined as having received a viral respiratory vaccination prior to shipping. In 2003 premiums as great as USD $1.57 per cwt were estimated for preconditioned calves. Over the duration of the study, the percentage of lots reported to have received a viral respiratory vaccination increased substantially from less than 10% of lots in 1997 to over 50% of lots in 2003. Over time producers adjusted their management practices to capture premiums in the market. Management practices that are implemented by early adopters often receive premiums, but eventually practices become an expectation and premiums for such practices are lost.

Bulut and Lawrence (2007) estimated the value of certified vs uncertified vaccination, and the affect that weaning and vaccination have on the price of feeder calves. Calves certified vaccinated and weaned (at least 30 days) received the highest premium USD $6.12 per cwt, followed by $3.35 per cwt for uncertified vaccinated and weaned (at least 30 days). Calves that had been vaccinated and weaned (no date or less than 30 days) received a premium of $3.12 per cwt, calves that had been vaccinated but not weaned received a premium of $2.41 per cwt, and the smallest premium of $1.66 per cwt was given to weaned but not vaccinated calves. Results confirm that without third-party certification preconditioning claims lose some credibility.

Seeger et al. (2011) analyzed the price effect of certified health programs for feeder calves. Each lot of calves included in the certified health programs were verified by the auction service and were uniquely identified in the sale catalogue with a special stamp. The number of lots with certified vaccination programs increased steadily over the time of the study, for the V45 program during 2005 through 2009 the number of lots certified was approximately 25%. Results showed significant premiums throughout the 15-year study for certified vaccination programs when compared to non-certified vaccination. Premiums for the V45 program ranged from USD $3.33 to $4.06 per cwt from 1996 to 2001.

Zimmerman et al. (2012) included preconditioning, weaning status, and vaccination programs as independent variables in their hedonic pricing model. The variable “VACPC” was used to describe calves that have been preconditioned, weaned for 60+ days prior to shipping and have been vaccinated.[11] The average premium for preconditioned steers over the ten-year period

[11] VACPC: Pre-weaning: first-round vaccinated against: IBR and PI3, BVD and BRSV, Mannheimia haemolytica and/or Pasteurella multocida, Clostridial 7-way Weaning: second-round vaccinated against: IBR and PI3, BVD and

is USD $2.26 per cwt. In 2007 the highest premiums were received for preconditioned steers at $5.73 per cwt. This study only included data for preconditioned heifer calves from 2005 through 2010 where the average premium was $0.61 per cwt and three out of five years preconditioned heifers were discounted. More research should be done to determine the premiums for preconditioned heifer calves. This study also included an independent variable for weaned status, premiums for weaned steer calves ranged from $1.88 per cwt in 2001 to $5.42 per cwt in 2009. Premiums for weaned heifer calves were also at their lowest in 2001 ($1.99 per cwt) and highest in 2009 ($5.15 per cwt). This study also analyzed the price effect of various other vaccination programs and found premiums associated with vaccinate of feeder calves, when compared to calves that had not received any vaccinations. The Canadian study by Carlberg and Hogan (2013) found no evidence of premiums associated with preconditioning programs (vaccinations and weaning) for feeder calves.

3.5 Conclusion

The main factors influencing the sale price of feeder calves have been thoroughly discussed throughout this literature review. Multiple studies have used the hedonic pricing model with OLS regression to estimate the price determinants for feeder calves; these studies are the foundation for this thesis and research. Many of the traditional attributes that have been included in previous feeder calf pricing models such base weight, lot size, gender, and flesh and frame size will be included within this research. The Canadian beef industry has changed since Carlberg and Hogan (2013) analyzed animals sold via live auction in Canada. This study includes new independent variables that have not been previously included in Canadian research for valuing feed calves, such as EU eligibility and VBP+.

BRSV, Mannheimia haemolytica and/or Pasteurella multocida, Clostridial 7-way, and Parasite control (optional) (Zimmerman et al., 2012).

Chapter 4. Theoretical Framework

4.1 Introduction

The objective of this chapter is to define key concepts used within the theoretical framework, to evaluate relevant theories and models used in previous research, and to provide background on the theoretical framework that supports this research. As the previous chapter showed, the hedonic pricing model has been used extensively since the 1980s to estimate the value of feeder cattle characteristics. Canadian beef production and an outline of the theoretical framework of derived demand for feeder calves can provide information on how the value of feeder calves is determined within the market. Management and production decisions made at the cow-calf level can affect price received for calves as well as have an indirect influence on the value of beef throughout the supply chain. Vertically coordinated production and marketing has become more important in the beef industry to focus on improving product characteristics desired by beef consumers (Zimmerman, 2010).

4.2 Beef Production Recap

Chapter 2 provides a more detailed description of the Canadian beef industry, and the role cow-calf producers play in the beef supply chain. In summary cow-calf producers raise calves with the intent to either retain them as breeding stock or sell them to a backgrounding, stocker, or feedlot operation. The goal of feeding operations is to compile groups of similar calves that will gain at a similar rate with proper health and nutrition programs. Stocker operations will purchase lighter weight calves that are not ready to go on a grain-based diet, they will instead graze them on pasture grass over a period of a few months (typically June through August) and then sell the calves to the feedlot sector. Another option for calves after they have been sold is to enter a backgrounding operation, where calves progress in a feedlot environment and slowly transition from a forage-based diet to a grain-based diet (*The Canadian Cattlemen's Association*, 2013). Lastly calves can transition from the ranch of origin directly to a feedlot operation where they will grow on a grain-based diet and be fed to slaughter weight. Ultimately most feeder calves will eventually end up at a feedlot operation where they will be fed a grain-based ration until they reach slaughter weight and then are sold to meat packing and processing plants. The meat packing sector is where the beef is processed for consumption and prepared to be marketed to the consumer. The production function used is from Zimmerman (2010). The production function can be summarized using the following three equations:

$$Q_{Feeder\ Cattle} = f(Q_{Calves}, Q_{Other\ Inputs}) \tag{4.1}$$

$$Q_{Fed\ Cattle} = f(Q_{Feeder\ Cattle}, Q_{Calves}, Q_{Other\ Inputs}) \tag{4.2}$$

$$Q_{Beef} = f(Q_{Fed\ Cattle}, Q_{Other\ Inputs}) \tag{4.3}$$

As can be seen in Equations (4.1) to (4.3), there is interdependency in the beef supply chain; each production phase requires a particular input – the feeder animal - from the previous phase. Equation (4.1) states that the quantity of feeder cattle in the stocker and backgrounding sectors is a function of the quantity of calves produced by cow-calf operations and all other inputs. Other inputs include land, infrastructure, medication, feed, and labor. Equation (4.2) explains that the quantity of fed cattle is a function of feeder cattle, and cow-calf numbers as well as additional inputs. Equation (4.3) is the quantity of beef produced, is a function of fed cattle and all other inputs required during the packing and processing stage of the supply chain.

These are simple production function equations that highlight the importance that feeder calf characteristics have an effect all the way through the supply chain, until the product of marketable beef is achieved. There is a level of interdependence through the supply chain, as some programs such as EU export require calves to not be implanted throughout their whole lives, therefore the choices made at the cow-calf level influence other areas along the supply chain. Calf attributes and characteristics play a role in the success of the stocker, backgrounding, and feedlot sectors. There are traits that benefit the feedlot's efficiency when finishing calves such as lot size, breed, gender, uniformity, frame and flesh, but there are also traits that affect how animals are marketed to packing plants such as if they are EU eligible, natural or not implanted, or if the operation of origin participates in VBP+. For these reasons, feeder calf prices should be determined by cattle buyer's willingness to pay for different calf attributes that affect both marketability of the calves and feeding efficiency.

4.3 Derived Demand for Feeder Calves

The theoretical backing for the derived demand for feeder calves can be explained using the foundation established by Ladd and Martin in “Price and Demands for Input Characteristics” (1976). This research analyzes the demand for corn based on production and profit functions. This foundational theory can be applied to many different agricultural commodities including feeder cattle. The following equations in this section have been adapted from Zimmerman (2010).

Equation (4.1) is a basic production function for feeder cattle starting from the cow-calf sector, this equation can be rewritten, where Y is $Q_{Feeder\ Cattle}$, X_1 is Q_{Calves} and X_2 is $Q_{Other\ Inputs}$:

$$Y = f(X_1, X_2) \tag{4.4}$$

Now the profit function for feeder cattle producers can be derived from Equation (4.4) the production function, where π is profits, p is the price of feeder cattle, and r^1 and r^2 are the price of calves and all other inputs in feeder cattle production, respectively:

$$\pi = pf(X_1, X_2) - r_1X_1 - r_2X_2. \tag{4.5}$$

The first derivatives of Equation (4.5) with respect to the inputs X_1 and X_2 are the first order conditions and they represent marginal value to production for each input:

$$\frac{d\pi}{dX_1} = p\frac{dY}{dX_1} - r_1 \tag{4.6}$$

$$\frac{d\pi}{dX_2} = p\frac{dY}{dX_2} - r_2 \tag{4.7}$$

The first order conditions equations (4.6) and (4.7) can now be expressed as the marginal value of production MVP_i, from the i^{th} input and MVC_i is the marginal factor cost of the i^{th} input:

$$MVP_1 = MVC_1 \tag{4.8}$$

$$MVP_2 = MVC_2 \tag{4.9}$$

In this case MVP_i represents the change in marginal revenue that is associated with the change in the quantity of the i^{th} input used in the production process. MVC_i is the change in variable factor costs resulting from a change in input quantity of the i^{th} input. Factor demand equations can be solved for each production input using the first order condition equations (4.6) and (4.7). Equations (4.10) and (4.11) are the result of this showing that optimal input use is dependent on the price of the output (p) and inputs (r_1, r_2) used in the production:

$$X_1^* = f(p, r_1, r_2) \tag{4.10}$$

$$X_2^* = f(p, r_1, r_2) \tag{4.11}$$

Feeder calves are the foundation of the beef supply chain, they provide the production process with an input that no other inputs can replace or provide. The derived demand for feeder cattle will be based on Lancaster's (1966) arguments from "A New Approach to Consumer Theory". This theory assumes that consumers make choices and have preferences based on characteristics of a good, not the good itself.

Equations (4.10) and (4.11), the derived demand, can be simplified to produce an equation where P is the price of each of the following factors:

$$Q_{Calves} = f\left(P_{Feeder\ cattle}, P_{Calves}, P_{Other\ Inputs}\right). \tag{4.12}$$

Equation (4.12) shows that the quantity of calves demanded is a function of the price of feeder cattle, price of calves, and the price of all other inputs used in the production process of feeder cattle. This is the derived demand for feeder cattle that is supported by economic theory. When the price changes for feeder cattle and all other production inputs, a shift in the demand curve for calves will occur, but a change in the price of calves will result in a change along the demand curve for calves (Zimmerman, 2010).

4.4 Theoretical Pricing Model

This section will provide details on previous theories and assumptions made that support the argument that the price of an individual lot of feeder calves is influenced by calf characteristics. Equation (4.12) is the quantity dependent factor demand derived for calves and will provide an opportunity to better explain how feeder calf characteristics can influence the price associated with that input in the market. Ladd and Martin (1976) view a product as a collection of characteristics and then apply this to production inputs. The first theme of this paper is that the price of a purchased input equals the sum of the monetary value of the input's characteristics to the purchaser. This paper suggests that some inputs are substitutable. This does not hold true for calves; calves have attributes for which no other substitute exists. From Ladd and Martin we can infer that the price received for feeder calves is the sum of the values of the individual calf attributes.

Faminow and Gum (1986) state that when supply for a market is given, then calf prices are determined by the current demand for an individual lot of calves, therefore supply for feeder calves for a specific lot of calves at a specific sale is fixed. Market prices for feeder cattle are a reflection of the current supply and demand in the market at that specific point in time and individual lot characteristics influence the price of the lot of weaned calves. Much of the previous research (Schroeder et al., 1988; Zimmerman, 2010; Zimmerman et al., 2012) defined calf prices as a function of the physical characteristics (C) of a sale lot and the fundamental market forces (M) of aggregate supply and demand for feeder calves at the observed time:

$$Price_{it} = \sum_{k} V_{ikt} C_{ikt} + \sum_{k} R_{ht} M_{ht} + \varepsilon. \tag{4.13}$$

Equation (4.13) summarizes the hedonic pricing model relationship where i is an individual lot of calves, k is a specific trait, h is the market influence, and t is the auction date. The value of a specific trait in a sale lot is represented by V, and the effect of individual market forces on price is represented by R (Schroeder et al., 1988). The above equation indicates the price per hundredweight for each lot of calves is equal to the sum of the marginal value of production for each lot characteristic and the sum of influence of market forces at a particular auction.

Chapter 5. Methodology

5.1 Introduction

This chapter will explain why the hedonic pricing model was used for this research and provide a high-level overview describing the data. The data collection process and sources of data will be explained, and a description of model variables will be provided.

For this research, a linear hedonic pricing model was used to allow coefficient estimates to be presented on a dollar per hundred weight basis. This approach can be easily interpreted by industry. There are less drastic swings in cattle prices compared to other markets such as farmland valuation, where a semi-log transformation may be a better fit to explain price change by percent. The linear model will be used for the discussion of the results. Pooled model results using the semi-log form are included in Appendix B. It is important to represent and interpret results from more than one model transformation to ensure that the chosen specification is appropriate.

5.2 Data Source

For this thesis, lot listings are an invaluable source of information to determine how buyers value characteristics and attributes in the market. The Lot Listing Database consists of five years (2016-2020) of sales data collected from Western Canadian online auction sales.[12] Multiple fields of data have been collected and compiled into a large Microsoft Excel spread sheet containing 4,866 individual sale lots (3,235 steer, 1,631 heifer) representing 505,074 head.

Weekly online sales from August to December for 2016 through to 2020 and specialty calf sales were included in the dataset. January through March sales were not included due to fewer feeder calves in the 400 to 800 lb weight range being marketed during that time. Calves sold later are often backgrounded already and could be listed by a second owner, the scope of this research is to capture calves leaving their home of origin. There are seven auction companies/sales included in the database (Balog Auction, Bow Slope, Cudlobe Angus (specialty sale), DLMS, Dryland Cattle Trading Corp., SALE, and TEAM), Table 5.1 includes the number of head and number of lots per year included in the database for each auction company/sale for 2016 to 2020. Sale prices were recorded in CAN dollars per hundredweight ($ per cwt). Three auction companies accounted for 87% of the calves sold online and 86% of total lots sold for the timeframe considered in the study; The Electronic Auction Market (TEAM) (38%, 191,919 head), Southern Alberta Livestock Exchange (SALE) (31%, 155,291 head), and Direct Livestock Marketing Systems (DLMS) (19%, 93,645 head) (see Figure 5.1 and Table 5.1). Data for this research was collected from the DLMS

[12] The "Lot Listing Database" is a Microsoft Excel spreadsheet where each row represents a lot of calves sold online between August and December 2016 through 2020.

feeder sales every Thursday, TEAM weekly feeder sales every Friday, other specialty sales as they occurred and one yearly SALE online auction from August through to December.

Each of the online auction platforms prepare similar lot listing descriptions. Appendix (A) has screenshots of lot listing descriptions from lots sold in 2020 for DLMS, TEAM, and SALE. All auction companies include a section for health information on the lot, a check box for age verification is included for all five years for TEAM and DLMS and starting in 2018 for SALE lot listing reports. From 2016 to 2020 lot listing reports for DLMS and TEAM remained the same. TEAM is the only company that includes a check box for implant status.

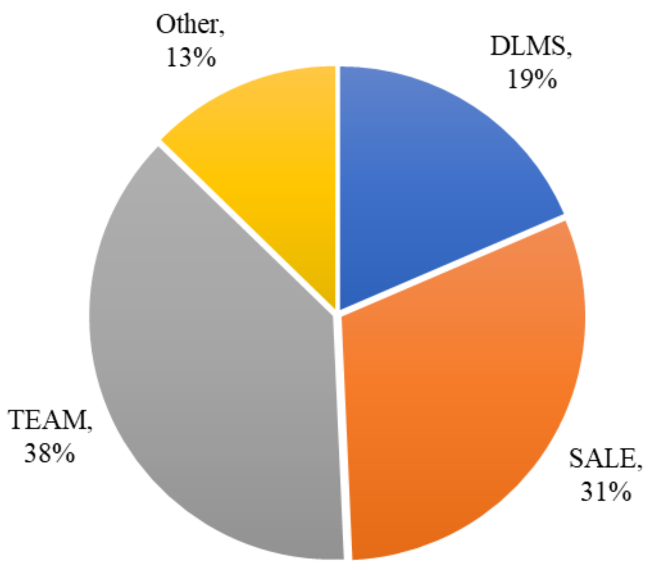

Figure 5-1. Percent of Total Number of Head Marketed by Auction Company, 2016 to 2020

Table 5-1. Number of Lots and Head by Auction Company and Year, 2016-2020

Auction Company/ Sale	2016		2017		2018		2019		2020		Total	
	No. of Lots	No. of Head	No. of Lots	No. of Head	No. of Lots	No. of Head	No. of Lots	No. of Head	No. of Lots	No. of Head	No. Lots	No. of Head
Balog	50	4,501	64	5,972	75	6,505	99	9,545	105	9,586	393	36,109
Bowslope	19	1,972	20	2,000	24	2,133	15	1,380	20	1,713	98	9,198
Cudlobe	0	0	13	2,080	10	1,450	11	1,610	9	1,385	43	6,525
DLMS	145	16,397	117	14,107	188	20,671	185	22,692	175	19,778	810	93,645
Dryland	43	3,497	35	2,830	24	2,070	22	2,110	20	1,880	144	12,387
SALE	267	28,487	304	34,934	212	22,649	309	34,166	323	35,055	1,415	155,291
TEAM	321	31,727	347	33,342	451	43,931	404	39,345	440	43,574	1,963	191,919
Total	845	86,581	900	95,265	984	99,409	1,045	110,848	1,092	112,971	4,866	505,074

Canfax regularly prints the lot listing reports for the online sales, but currently does not enter the lot description details into an electronic format for use in market analysis. Canfax provided hardcopies of the lot listing reports and digital online sales results. Lot listing reports were scanned to PDF and details for each lot were manually entered into a Microsoft Excel spreadsheet (the Lot Listing Database) where each row represents one lot.[13] The majority of the lot listing reports included the following information: the number of animals for sale (lot size); the consigner (owner); base, minimum and maximum weight of animals in lot; location (nearest town, province) of the cattle; delivery date; percent shrink; slide; frame category (percent small, medium, large); flesh category (light, medium, heavy); quality (percent good, medium); breed(s), sex, hide colour, current diet, weigh scale location, conditions for weighing on shipping day, health program of the animals, field agent, and any additional comments about the cattle for sale. Refer to Table 5.2 for an explanation of all fields entered in the Lot Listing Database.

The focus of this study was spring-born feeder calves – both weaned and unweaned – sold between the months of August to December for the years 2016 through 2020. Online auction sales may have more than one class of cattle to sell – yearlings, calves, bred females – so criteria were established to identify which lots were "feeder calves" within each sale. Both DLMS and SALE make a distinction between yearling and calf lots in their lot listing report, therefore additional criteria were used to identify calf lots for the other auction companies. For a lot to be considered calves it met the following criteria: base (average) weight of the animals in the lot must be between 400 to 800lb; sale date was between August and December; terms such as "mother's milk" or "on cows" were included in the feed category of the lot description or the lot description provided details about the wean status for the calves.[14]

A list of assumptions used for entering the information from the lot listing reports into the Lot Listing Database can be found in Appendix (C). An advantage of this Lot Listing Database is that all lot listings have been recorded and analyzed using the same criteria. Human error is still a concern with this database, but there should be a high confidence level for the results as the evaluation protocol was consistent across all lot entries. No mixed gender lots were included in

[13] Future efforts to update the Lot Listing Database are encouraged in cooperation with the auction platforms to gain access to the electronic data used to generate the lot listing reports.
[14] Lot descriptions that included terms such as "mother's milk" or "on cows" in the feed category indicate that they are suckling calves and will be weaned once sold.

the database and all lot listings with incomplete information such as passed (no-sale) lots were removed. Lots sold by Canadian Satellite Livestock Auction were removed from the database as information contained in lot listing reports was inconsistent.

Table 5-2. Explanation of Fields Entered into the Lot Listing Database

Field Name	Type	Explanation
Sale Date	Date	Date (DD-MMM-YY) of sale as per lot listing report
Auction Company	String	Name of company that lot sold through (e.g. SALE, TEAM, DLMS, BALOG)
Lot Number	Numeric	Number of the lot, as per lot listing report
Number of Head	Numeric	Number of head in lot (lot size)
Price	Numeric	Price received per hundredweight ($/cwt)
Sex	String	S=Steer, H=Heifer
Base Weight	Numeric	Estimated average weight per calf in the lot in pounds (lb)
Weight Min	Numeric	Estimated weight (lb) of lightest calf in lot
Weight Max	Numeric	Estimated weight (lb) of heaviest calf in lot
Consigner	String	Name of the individual(s) offering the lot for sale
Shrink	Numeric	A value in percent chosen by the consigner; animal pay weight reduced by this percent to account for weight loss due to transport and stress
Slide	Numeric	A value used to adjust sale price if actual animal weight differs from the base weight at time of delivery
Scale Location	Numeric	Distance from the location the cattle are loaded to the scale where they are weighed at time of delivery, all distance have been converted to miles
Frame Size	Numeric	Percentage of animals in lot that have small, medium, or large frames
Flesh	String	Body condition of the cattle light, medium, heavy or combination thereof
Delivery Date Start	Date	The first day that the cattle may be picked up
Delivery Date End	Date	The last day that the cattle may be picked up
Breed	String	Breed makeup of calves in lot
Color	Numeric	Percentage of coat colour(s) in the lot- Black, Red, Black/BWF, Red/RWF, Tan, Silver, BWF, RWF, Hereford, Charolais, Mix
Feed	String	Current feeding information for calves
Health	String	Information provided by the consigner on the health of the cattle, may include product names of vaccinations or medications previously given, castration type, implant status and any certifications of the calves or operation (e.g., VBP, EU)
Castration	String	Status of castration, type of castration (e.g., banded or knife cut) - steer lots only
Age Verified	Yes/No	Yes - cattle are age verified; No - lot indicated calves are not age verified or no information is provided
VBP+	Yes/No	Yes - listing mentions Verified Beef Production+ certified operation; No - listing does not mention VBP+
Implant Status	Yes/No/Not Specified	Yes - calves in the lot have received a growth promoting hormone (implant); No - calves have not been implanted; Not Specified - lot does not include details about implanting
Quality	Percentage	Quality of calves in the lot. Estimated in percent of good and medium quality
Town/City	String	Closest town/city to the location of the calves listed
Province	String	Province the calves originate from
Comments	String	Includes all additional information that the consigner and field agent would like to include about the lot
Field Rep	String	Auction company representative who described the calves and is responsible for listing the lot

5.3 Description of Model Characteristics

This section will discuss how model characteristics were refined and selected as variables in the hedonic model evaluating the price impacts of attributes for fall-sold online-marketed calves in Western Canada. The independent variables included in the hedonic pricing model were selected with careful consideration of previous research discussed in Chapter 3; current and past market trends; and consultation with industry stockholders in May/June 2020. Similar to Schultz et al. (2010) and Zimmerman (2010), the model's independent variables are organized into lot, genetic, management, marketing and market characteristics. Table 5.3 shows the independent variables used in the model.

Table 5-3. Independent Model Variables

Characteristic	Description	Model Variable
Intercept	Intercept	Intercept
Lotsize	Number of head in a lot	Lotsize
Lotsize^2	Number of head in a lot squared	Lotsize^2
Wt	Average base weight (lb) of lot	Wt
Wt^2	Average base weight (lb) of lot squared	Wt^2
Weight Variation	Even (less than 100 lb spread)	WV_Even
	Uneven (100-199 lb spread)	WV_Uneven
	Very Uneven (over 200 lb spread)	WV_Vuneven
Week	The week number of the sale	Wk
Frame	Small to Small-Medium Mix	Frame_SM
	Medium	Frame_M
	Medium-Large Mix	Frame_ML
Flesh	Light	Flesh_L
	Light-Medium Mix	Flesh_LM
	Medium to Heavy	Flesh_MH
Implant	Not Implanted	No_IMP
	Implanted	IMP
	Not Specified	IMP_NS
VBP+ Operation	Not Specified	VBP+
	Operation Mentioned VBP+	
Age Verification	Not Specified	AV
	Age Provided to CCIA	
EU Eligible	Not Specified	EU
	Lot mentions EU eligibility	
Weaned	Not weaned	Wean
	Weaned	
Hide/Coat Colour	Black	Hide_Blk
	Charolais Influence	Hide_Char
	Red	Hide_Red
	Mixed	Hide_Mix
Location	British Columbia	Loc_BC
	Alberta	Loc_AB
	Saskatchewan	Loc_SK
Days to Delivery	Days between sale date and delivery date	DTD
Expected Fed Price	Expected fed cattle price, based on LPI*	Exp_Fed_P

***LPI: Livestock Price Insurance Fed Cattle Index**

5.3.1 *Lot Characteristics*

Lot characteristics included in the model are, province of origin, gender, and lot size. Year was only included as an independent variable in the pooled models. Separate models for each year (2016 to 2020) were analyzed to identify any fluctuations in the market from year-to-year and to identify if any yearly trends were present. Sartwelle III et al. (1996) and Smith et al. (2000) found that year can be an important variable to include when analyzing feeder calf price differentials. The magnitude of price influence can vary widely year-to-year.

All lot listing reports provide a location where calves are to be picked up from at the specified delivery date(s). The database contains calves marketed online from three Western Canadian provinces British Columbia, Alberta, and Saskatchewan. Manitoba lots were excluded from the analysis, due to a low number of lots (~50 lots, ~1% of total lots) and it is common for calves marketed from Manitoba to enter the Eastern Canadian feeder calf market not the Western Canadian market. Three categorical variables were created to represent the province of origin for each calf lot in the database, where BC is used as the base province (BC=1, AB=2, SK=3). The majority of calf lots in the database originate from Alberta (65%) followed by Saskatchewan (27%) and a small representation of overall lots from British Columbia (8%) (see Figure 5-2).

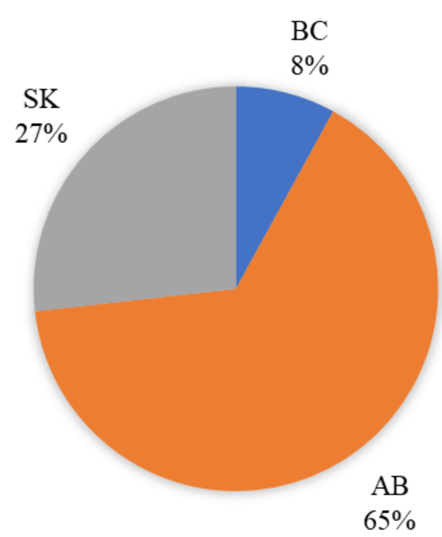

Figure 5-2. Distribution of Lots by Province, 2016 to 2020

Some studies (Blank et al., 2009; Carlberg & Hogan, 2013) include both steer and heifer lots in the same model while other studies (Schroeder et al, 1988; McCabe, 2018; Zimmerman, 2010; Zimmerman et al., 2012) model steers and heifers separately. For this study separate models will be used, one for steers weighing 400 to 800lb and another for heifer calves weighing 400 to 800lb. This decision was based on research done by Bailey et al. (1993) and Schroeder et al. (1988) where they made the argument that cattle gender and weight have an influence on calf markets. Having separate heifer and steer pricing models within a specific weight range captures the varying preferences of buyers across different classes of cattle. When cattle buyers attend a sale, they are often there with intent to purchase calves of a specific gender and weight. Out of 4,866 lots in the database 3,235 are steer lots and 1,631 are heifer lots.

Lot size is an important characteristic that has been included in most hedonic pricing models for feeder cattle starting with Williamson et al. (1961). It was Faminow and Gum (1986) who first presented the idea that lot size had a non-linear influence on price. Since their research, hedonic feeder cattle pricing models have included both lot size and lot size squared variables. Much of the previous research (Avent et al. (2004), Bailey et al. (1993 and 1995), Schroeder et al. (1988), Zimmerman (2010) and Zimmerman et al. (2012)) found that increasing lot size positively effects price at a decreasing rate. Average lot size for the Lot Listing Database for steers is 109 head with a standard deviation of 60.52 and average lot size for heifers is 94 head with a standard deviation of 55.21. The lot size variable is centered to the mean, where the raw data for number of head per lot was subtracted from the average lot size for all lots in the dataset. Figure 5.3 shows the distribution of lot size for the dataset for steer and heifer lots combined; the majority of lots (53%) were between 51 and 100 head.

5.3.2 Genetic Characteristics

Genetic characteristics are those influenced predominately by breed makeup of the calves and includes the variables for hide colour and frame size. These characteristics can be seen by visually observing the animals (photo or video).

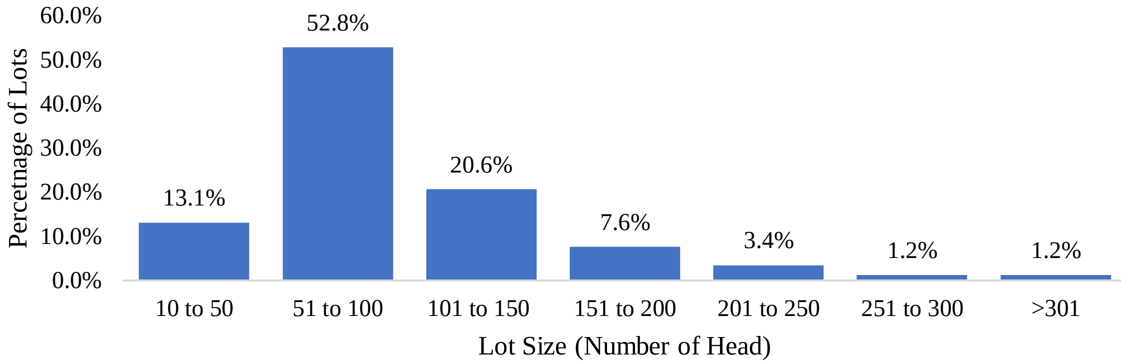

Figure 5-3. Distribution of Lot Size, 2016 to 2020

Breed influence has been modeled a variety of ways with each study being specific to that particular dataset and research question. The most recent studies done by Smith et al. (2000), King et al. (2006), Schultz et al. (2010), Zimmerman et al. (2012), and McCabe (2018) show that breed has a significant influence on sale prices of calves. Breed is an indicator of performance potential for buyers, as each cattle breed is uniquely known for their performance characteristics.

During the data entry process the specific breed(s) that were reported for each lot description were entered into the breed category in the database. Some lots did not include breed information and were classified as "not specified" (282 lots; 5.8%). There were a wide variety of breeds listed but the percentages of each breed were not always reported, including many crossbred calves with genetic influence from multiple breeds. Simmental, Angus (red and black), Charolais, Hereford, Limousin, and Gelbvieh are among some of the more common breeds identified. Angus influence was identified in 68% of calf lots in the database making it the most common breed influence in the dataset. The Angus breed (Red and Black Angus) has been in Canada since 1860, and is popular in Canada due to maternal instincts, marbling quality and being naturally polled (Canadian Angus Association, 2021). The strong presence of Angus influenced calves within the data set was expected as many Western Canadian producers use the Angus breed in crossbred and purebred cow herds. Due to collinearity issues with the many different breeds and crossbred combinations listed, no breed variables are included in the models.

Each lot reported the percentage of each hide/coat colour of the calves. Hide colour percentages for each lot were recorded in the Lot Listing Database. There are 11 hide colour categories: 1) Black, 2) Red, 3) Black and Black-White Face (BWF), 4) Red and Red-White Face (RWF), 5) Tan, 6) Silver, 7) Black-White Face, 8) Red-White Face, 9) Hereford, 10) Charolais, and 11) Mixed. The 11 hide colour categories were grouped into one of four categorical variables for inclusion in the model: 1) Black (base), 2) Charolais-influenced, 3) Red, and 4) Mixed. For a lot to be classified as "black", 80% or more of the animals in the lot must have been reported as black, black and black-white face or black-white face. For a lot to be classified as "Charolais-influence", 80% of the lot must be tan, silver, or Charolais (white). To be classified as "red hided", 80% of the lot must have been reported as red, red and red-white face, red-white face, or Hereford. The "mixed hide" category includes lots that do not fit into the first three hide colour categories. Figure 5.4 represents the overall distribution of hide colours in the database; 36% of lots were black hided; 17% of lots were red hided; 14% were Charolais-influenced hide colour; and 34% of lots were classified as having mixed hide colour. Table 5.4 provides a more detailed distribution of hide colour for steers and heifer calves in the dataset.

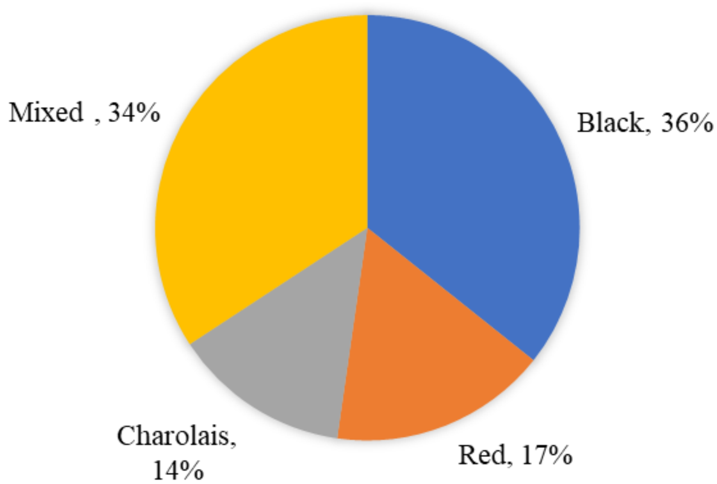

Figure 5-4. Percent Hide Colour of Overall Lots, 2016 to 2020

Table 5-4. Distribution of Calf Lots by Hide Colour Category for Steers and Heifers, 2016 to 2020

	Steers 400 to 800 lb		Heifers 400 to 800 lb	
Hide Colour	**# of Lots**	**% Total**	**# of Lots**	**% Total**
Black	1,210	37%	527	32%
Red	581	18%	226	14%
Charolais	326	10%	331	20%
Mixed	1,118	35%	547	34%
Total	**3,235**	**100%**	**1,631**	**100%**

Frame size is an attribute of calves that cattle buyers look at as an indicator of finished weight, how long an animal may take to reached finished weight and how much feed will be required to reach that weight. The lot descriptions reported the percentage of the animals in a lot that were small, medium, and large framed. These percentages were used to classify the frame size for each lot. Large framed animals typically take longer to reach finished weight and potentially may exceed the desired carcass weight of the packer and be discounted (Seeger et al., 2011). Results for frame size may vary by region and evolving cattle feeder preferences. No other Canadian research has been done including frame size, and US results show frame size does affect price with significance varying depending on the study.

For this research frame size was included as a categorical variable in the model. For each lot the percent of the frame size of animals with small, medium and large frame size was entered into the database. Three categorical variables were created for frame size: 1) Medium (lots with 100% medium), 2) Small to Small-Medium (lots with 100% small or a mix of small and medium), and 3) Medium-Large to Large (lots with a mix of medium and large or 100% large).[15] As shown in Figure 5.5 the majority of lots were categorized as medium-large to large (67% steer lots, 59% heifer lots). The next most common frame size and the base was medium (25% steer lots, 29% heifer lots), and the small to small-medium frame category had the fewest lots (7% steer lots, 13% heifer lots).

[15] For lots with percentages entered in all three frame categories, the category with the largest or majority percentage was used to categorize the lot.

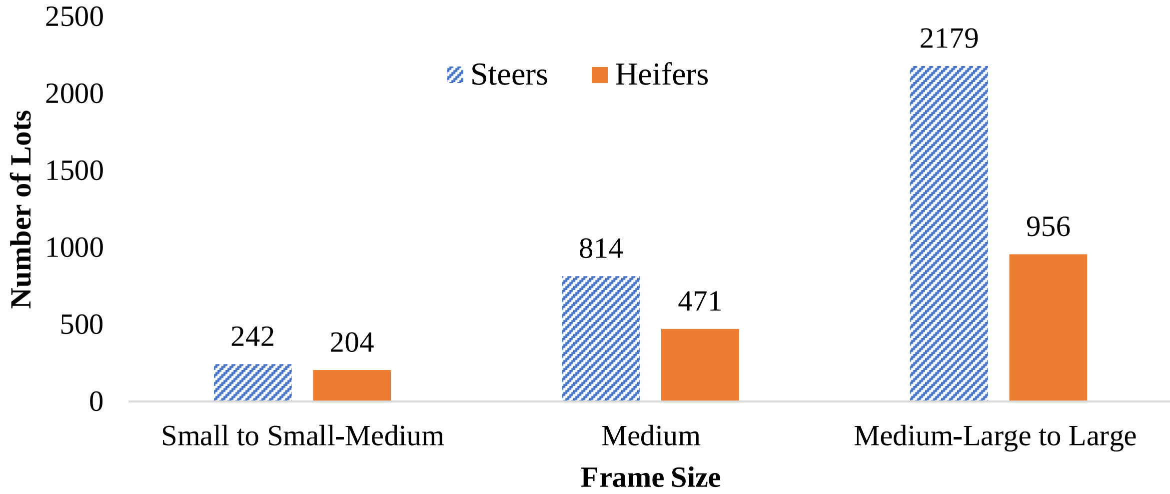

Figure 5-5. Distribution of Frame Size by Number of Lots, Steers and Heifers 400 to 800 lb, 2016 to 2020

5.3.3 Management Characteristics

Cow-calf producers have control on management characteristics of their calves, such as weight, weight variation, fleshiness, implant use and weaning status. Some of these characteristics can be visually observed by buyers, but others such as implant use and weaning status must be provided by the sellers. Health and vaccination protocol is an important management characteristic in much of the existing research done in the US, but for this study no variable related to vaccinations was included in the model. Information provided in the health field (veterinary work) of a lot listing would need further analysis and categorization to be used in the model, therefore vaccination information was omitted due to time constraints and the scope of this research.

The maximum, minimum, and base (average) weight for each lot is recorded in the Lot Listing Database. Base weight was included as a continuous independent variable in the model and represents the average weight of all calves in the lot. This study has defined calf lots as being those having a base weight range between 400 to 800lb (182 to 364kg). For steer calf lots the average base weight was 602.9lb (273.5kg) (SD:75.35) and 553.4lb (251kg) (SD:69.3) for heifer calf lots (Table 5.5). The base weight variable was centered to the mean for both steers and heifers for all lots. As shown in Figure 5.6 the majority (81% for steer lots, 78% for heifer lots) of lots are between 500 to 700lb. The chosen weight range for calves is consistent with previous research. The weight ranges used in Zimmerman (2010) were 450 to 700lb for steer calves and 400 to 700lb for heifer calves. Bulut and Lawrence (2007) used the weight range of 300 to 900 lb for calves, Schulz et al. (2010) used a range of 300 to 900 lb and Seeger et al. (2011) used 320 to 900 lb.

Table 5-5. Average Weight, Lot Size, and Sale Price for Steers and Heifers, 2016 to 2020

		Steer and Heifer Calves, 400 to 800 lb			
Gender	**Mean Variable**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
Steers	Base Weight (lb)	602.86	75.35	400	800
	Lot Size (# of Head)	108.88	60.52	10	625
	Sale Price ($ per cwt.)	$210.32	17.37	$149.00	$275.00
Heifers	Base Weight (lb)	553.37	69.30	400	800
	Lot Size (# of Head)	93.72	55.21	10	625
	Sale Price ($ per cwt.)	$191.11	16.64	$135.25	$244.00

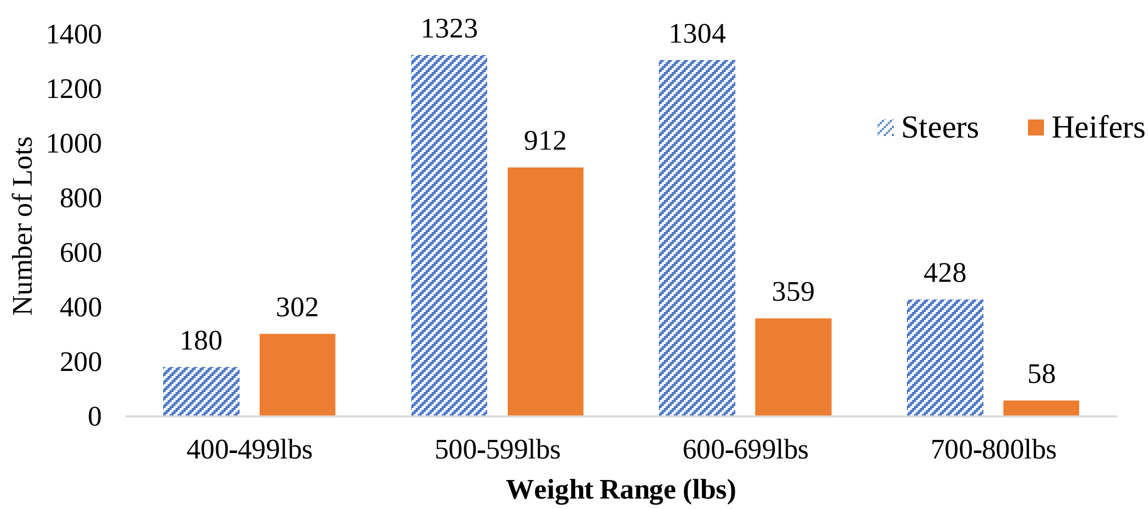

Figure 5-6. Weight Distribution of Steer and Heifer Calf Lots, 2016 to 2020

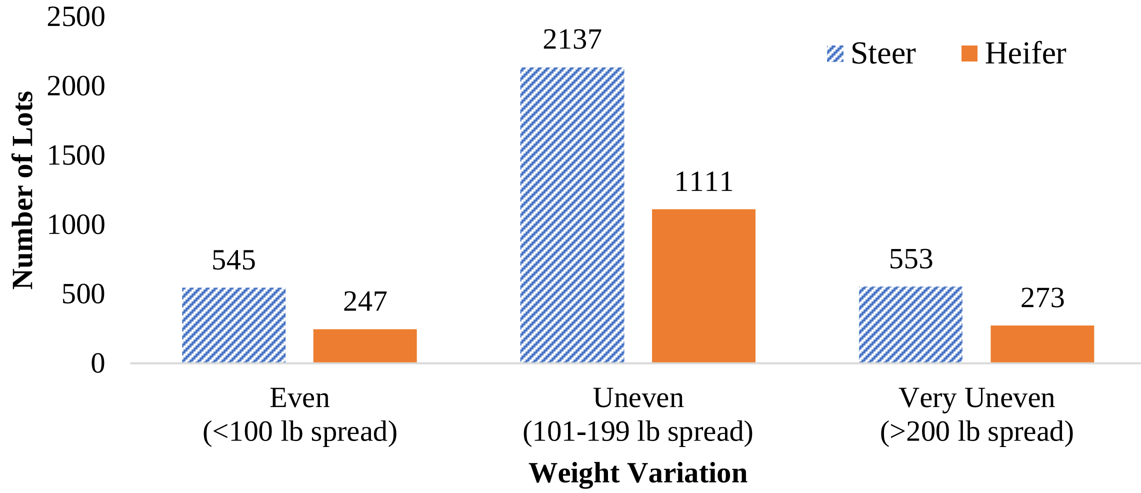

Figure 5-7. Weight Variation Distribution for Steer and Heifer Calf Lots, 2016 to 2020

Calves that are similar in weight and type that will feed well together are considered uniform. It is important to cattle feeders to have animals that will gain similarly and reach target weight at similar time points. One way to classify uniformity of calf lots is by weight variation. Weight variation or weight spread for each lot was calculated by subtracting the minimum weight from the maximum weight reported for each lot. Weight variation was found to be statistically significant in feeder calf pricing for Schroeder et al. (1988), Blank et al. (2006 and 2009) and Schulz et al (2010). Zimmerman (2010) also found premiums associated with lot uniformity and state that producers expect to receive a premium for more uniform groups of calves and more even calculated weight distribution of calves is more convenient for cattle feeders.

The weight spread for each lot was classified as either: 1) uneven, 2) even or 3) very uneven. Lots classified as "even" had a weight spread less than or equal to 100 lb, "uneven" lots were those with a weight spread between 101 and 199 lb, and "very uneven" lots had a weight spread greater than or equal to 200 lb. Figure 5.7 shows the number of lots per weight spread category. Two thirds (67%) of the lots in the dataset are considered to have uneven weight distribution, 17% of the lots are very uneven and 16% of lots are even.

Fleshiness is an attribute that can be influenced by calf management and diet. Each lot listing includes information on the fleshiness of a lot of calves, but how the information was presented differed. TEAM lot listings included a table where percentages were reported for the lot for body condition (flesh), SALE had a combination of percentages and word categories for the flesh category, and DLMS only included a word category for fleshiness of the lot. The word categories provided on the lot listing reports matched categories outlined for the study, they are entered verbatim. Some reports included percentages and were categorized as follows: if a lot was split in half into two categories, then it would be categorized as both (ie. Light to medium, or medium to heavy); if a lot had a flesh combination of 60% or less for one category then the lot would be classified as both flesh types included; if the lot had one category greater than 60% then the lot was categorized based on the 60%. From the percentages and word categories lots were categorized as one of five options light (25.8%), medium (52.5%), heavy (0.3%), light to medium (21.3%), or medium to heavy (0.1%) flesh. From the five options three categorical variables were created: 1) Medium to Heavy, 2) Light to Medium, and 3) Light. Approximately half (53%) of the lots are medium to heavy flesh and a similar distribution for light to medium (21%) and light (26%) flesh.

Weaning and pre-conditioning are attributes that have been considered in some, but not all of the existing literature (Bulut and Lawrence (2007), Zimmerman (2010), Carlberg and Hogan (2013), and Schulz et al. (2015)). In much of this research preconditioning program claims are associated with higher prices. Both preconditioning claims and weaning status were recorded in the Lot Listing Database. The listing descriptions do not include standalone fields to report preconditioning or wean status, instead this information must be included by the producer in the comment or health fields, where they provide information on the preconditioning practices for the lot and the number of days weaned. The quantity of lots that mentioned preconditioning claims was very low (0.7%) so the decision was made to group preconditioned lots with lots that noted calves were or would be weaned prior to the delivery date of the cattle. For a lot to be considered weaned the claim stating the calves have been weaned from the mother's "X" amount of days or the date they were weaned must be included in the lot listing. Not all weaned calves were preconditioned as this is a grouped field with both weaned and preconditioned calves. Only 35 lots had preconditioning claims, 40 lots had both weaned and preconditioned claims, and 205 lots had weaning claims. An independent binary variable where 1=weaned and 0=not weaned was included in the model; in total 280 lots or 6% of total lots in the database were classified as weaned. Unlike some US studies, Canada's preconditioned and weaned claims are not third-party certified, nor do they have specific requirements or definitions.

Implant status of calves is potentially one of the most discussed management practices by cow-calf producers. This is a variable included in much of the existing research and can be represented by implant status or by hormone claims, such as in Carlberg and Hogan (2013). A variable considering growth-promoting implants was included in Seeger et al. (2011) and Zimmerman et al. (2012). Many third-party certified value-added programs related to hormone free or natural beef are available in the US through Superior Livestock Auction. These programs have been analyzed in detail by Bulut and Lawrence (2007), Zimmerman (2010) and Zimmerman et al. (2012).

Following Zimmerman (2010), lots were classified into one of three categorical variables for implant status: 1) Implanted (base), 2) Not Implanted, and 3) Not Specified. Over the five years (2016 to 2020), 35% of lots stated calves were implanted, 40% stated calves were not implanted and 26% did not specify implant status in the lot listing description. Figure 5.8 shows the distribution of implant status for both steers and heifers. The majority of steer calves (41%) are implanted and the majority of heifer lots are not implanted (48%), 23% of steer lots and 31% of heifer lots have an unspecified implant status.

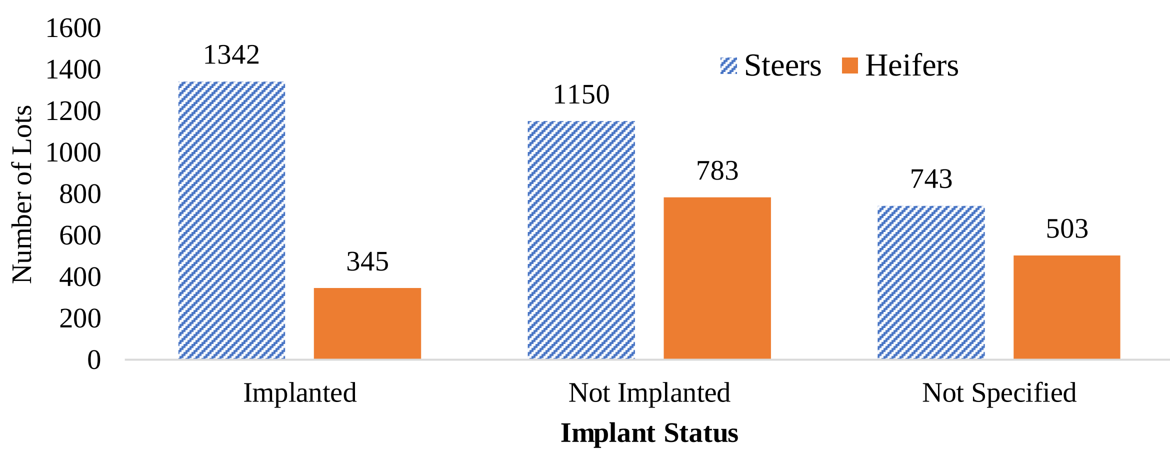

Figure 5-8. Distribution of Implant Status for Steer and Heifer Calf Lots, 2016 to 2020

5.3.4 Marketing Characteristics

There are some value-added marketing opportunities that cow-calf producers can utilize in hopes to receive premiums when they market their calves. Some value-added opportunities are GEP free markets (such as the EU and natural beef programs), Verified Beef Production Plus (VBP+) certification, and Age Verification which are explained in Chapter 2.

Exporting Canadian beef to the EU is a relatively new market opportunity for non-implanted calves. This study included an EU eligible variable to determine if having calves eligible for EU export yields a premium. In the lot listings producers identify cattle as EU Certified, natural or eligible for an EU program. There are differences in the various EU claims made in the lot listings, “EU Certified” may not be the same as “EU eligible” or “natural”. From the lot listing reports any mention of EU certification, verification or eligibility was recorded utilizing a binary variable where 1= EU eligibility mention and 0 = no mention of EU eligibility. Only four percent of total lots made EU claims, given CETA was only ratified in 2017 it was not surprising zero lots made EU claims in 2016.The percent of steer calves with EU mention increased yearly from 2017 to 2020, from less than one percent in 2017 to nine percent in 2020.

Only producers who have been successfully enrolled in the GEPs program would have “EU Certified” calves. There is no clear definition of the term “EU Eligible” when it is included in lot listing reports; it is unknown if these cattle come from an EU certified operation or if they simply have not been implanted. More clarity is needed within the industry surrounding EU eligibility and to validate claims made within lot listing reports.

Producers who are VBP+ certified operations have been audited and are held to strict standards for beef production and environmental stewardship. Feedlot operations can also be VBP+ operations. There are financial incentives for animals that have been raised and fed through the whole supply chain on VBP+ operations since 2018 (Cargill, n.d). Carlberg and Hogan (2013) did not include VBP+ mention as a variable in their 2011/12 study. A binary variable was created to identify lots where the consigner mentioned VBP+ (1=VBP+ mentioned, 0=VBP+ not mentioned). Only seven percent of total lots are from VBP+ operations. Figure 5.9 shows the percent of yearly lots that mention VBP+; over the five years VBP+ mention gradually increased for both steer and heifer lots so that by 2020 15% of steer lots and 13% of heifer lots mentioned VBP+.

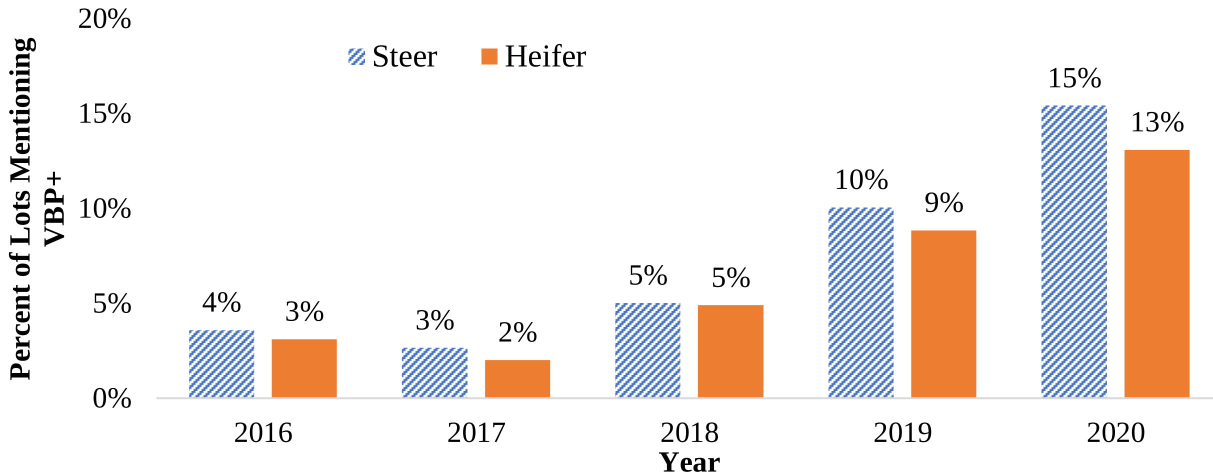

Figure 5-9. Percent of Steer and Heifer Lots Mentioning VBP+ by Year, 2016 to 2020

Age and source verification is a common characteristic analyzed in hedonic pricing models of feeder calves. Much of the existing research in the US found age and source verification produced statistically significant premiums (Blank et al., 2009; King et al., 2006; Zimmerman et al., 2012). Age verification is currently voluntary for producers in Canada. Figure 5.10 provides the number of age verified steer and heifer calf lots by year and the total percent of lots by year. The number of age verified lots stayed consistent from 2016 to 2020, but there is a decreasing trend in the percentage of lots being age verified (58% in 2016 and decreasing to 46% in 2020). A binary variable was used to categorize lots as either mentioning age verification (1) or not mentioning (0).

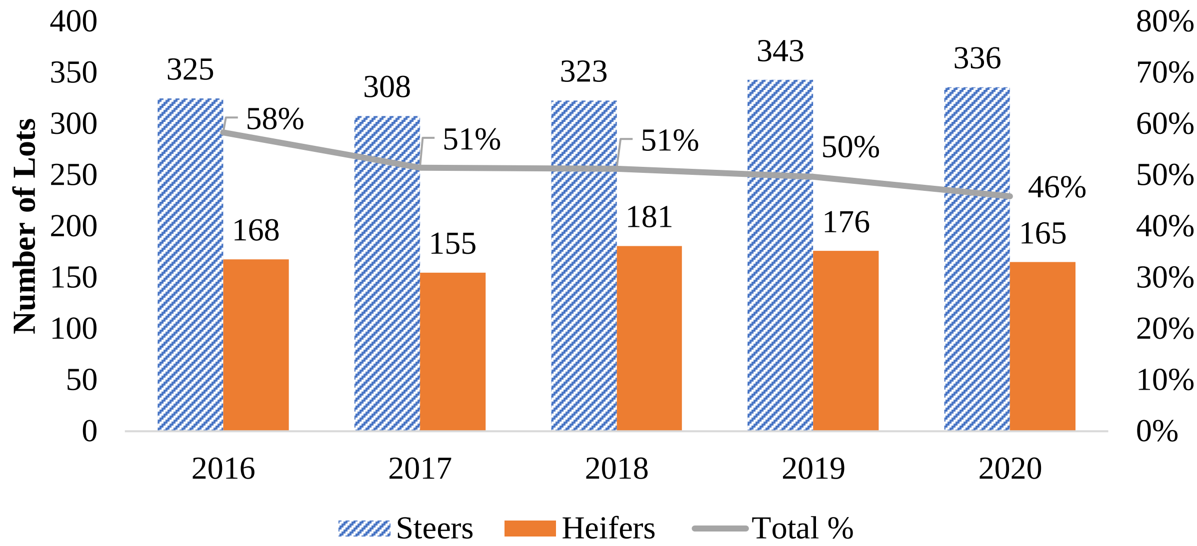

Figure 5-10. Number of Age Verified Steer and Heifer Calf Lots, by Year and Total Percent, 2016 to 2020

5.3.5 Market Structure Characteristics

The following section will discuss the market structure variables included in the model: days to delivery, marketing week, and expected fed price. Market structure variables are those factors that may influence the price of calves from week to week during the fall when most spring-born calves are marketed. The number of days between the sale date and the delivery date may influence the overall lot price, as buyers may prefer to have calves delivered later or earlier. The futures price influences the expected slaughter price for the calves and therefore what the buyer is willing to pay for the calves. Values for the expected fed price are based on index offerings for the Livestock Price Insurance's Fed Program. The expected fed price is used as a proxy for CME's live (fed) cattle futures price.

The days to delivery was calculated using the date a lot of calves was sold and the earliest date the lot description states calves can be picked up, the difference between these two dates is the number of days to delivery. The average days to delivery was 32 (SD:19, Range:0-161 days), with 96% of lots noting delivery within 60 days of the sale date (see Figure 5.11). Zimmerman (2010) included a days to delivery variable and found that as the number of days between the sale date and the delivery date increased, calf price was negatively affected. McCabe (2018) also included a days to delivery variable, but results were not statistically significant.

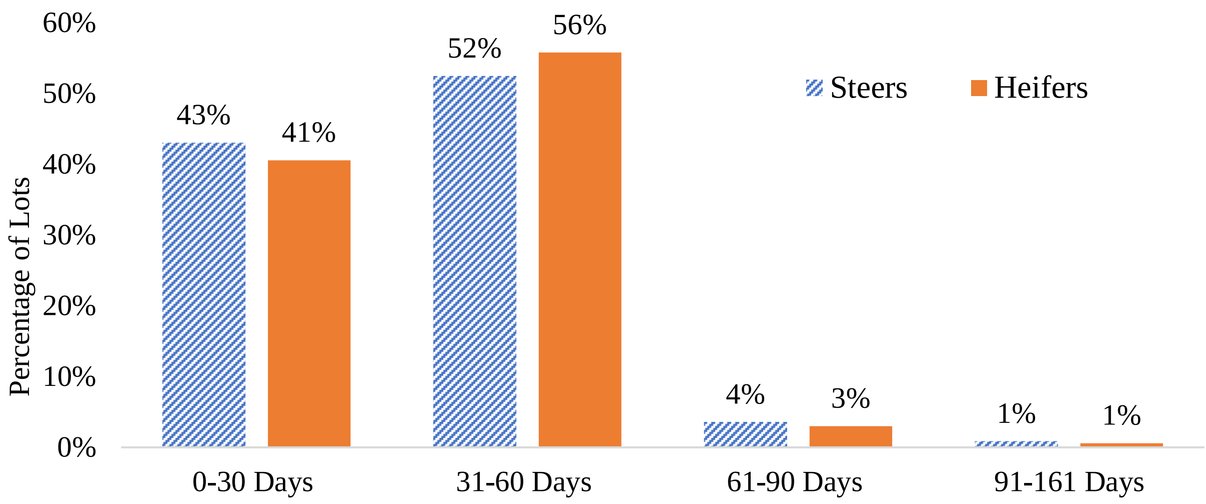

Figure 5-11. Distribution of Days to Delivery of Steer and Heifer Lots, 2016 to 2020

The week number of each sale was calculated from the sale date using Microsoft Excel's "WEEKNUM" function. Week number was included as an independent variable in the model because calf prices tend to decline as sale volumes increase in the fall. The database contains lots sold from August to December (week 32 to week 52) each year. The most common (mode) marketing week was week 37 (the second week in September), when 31% of total lots were sold (see Figure 5.12). Using the week variable provides more specific information on the price of calves than a month variable.

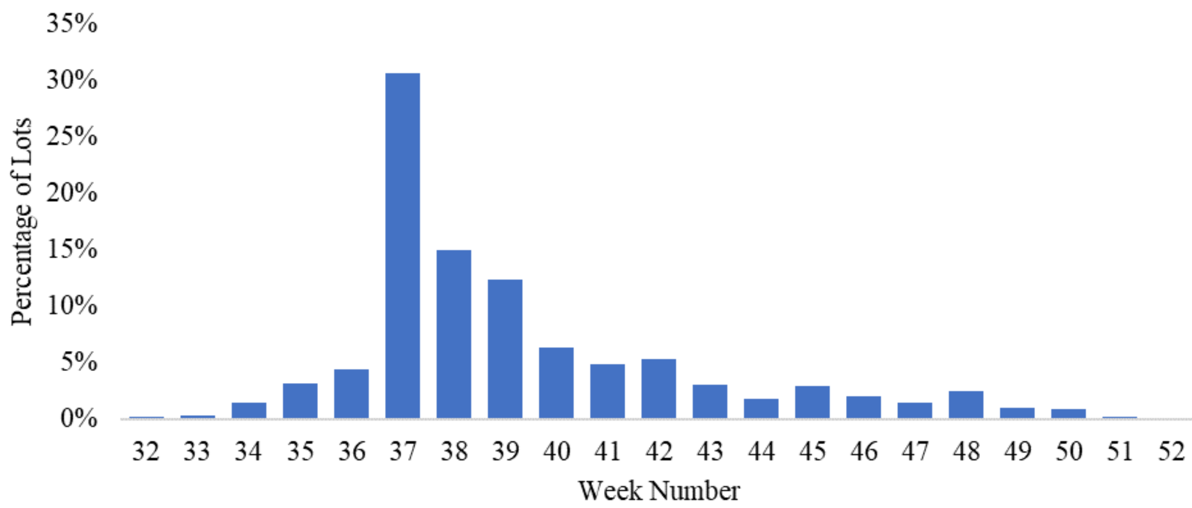

Figure 5-12. Percentage Distribution of Lots Sold by Week Number, 2016 to 2020

Including live cattle futures as an independent variable in hedonic models is essential to aid in understanding how the expected price of finished cattle influences cattle buyers' willingness to pay for feeder calves. This research utilized insured index values from the Livestock Price Insurance (LPI) Fed Program as a proxy for futures prices to estimate an expected fed price for each lot. This approach differs from the other Canadian study (Carlberg and Hogan, 2013) which used nearby CME fed cattle futures. The following paragraphs will justify and explain this approach.

Livestock Price Insurance is a risk management program to protect Western Canadian livestock (beef and hog) producers from downturns in the market. LPI has offered a fed, feeder and calf program since 2009 in Western Canada. The coverage levels for the fed program are based off the Chicago Mercantile Exchange's Live Cattle Futures, converted to Canadian currency using forward-currency-exchange data and adjusted for basis. The fed program is offered year-round with premium offerings released Tuesday, Wednesday, and Thursday of each week (SCIC, n.d). Policy lengths range from 12 to 36 weeks in four-week increments (12, 16, 20, 24, 28, 32, and 36 weeks). The coverage ranges from 75 to 95% of the expected forward price for each policy length.

When a buyer is contemplating the purchase of feeder calves, they need to consider what the animals will be worth when they are ready to be sold for slaughter. The live cattle futures for the expected month of slaughter is an indicator of what the value of the animals will be. Pugh (1986) developed an equation for predicting feeder calf pricing where the price for a feeder calf (FP) is based on the expected slaughter price (SP_e) in \$ per cwt when the animal reaches slaughter weight (SW), starting weight (FW) and cost of gain (CG). The price that a feedlot owner is willing to pay for a feeder calf is based on what price the animal can be sold for and the cost of the gain (Equation 5.1).

$$FP = SP_e + [\frac{(SW - FW)}{FW}(SP_e - CG)] \quad (5.1)$$

For this research, the assumption was made that all animals are entering a feedlot operation to be fed to finished weight. In all likelihood, lighter calves would be backgrounded (target 2 lb/hd/d gain) until they reach 800 lb, and they would either enter the feedlot or be placed on pasture to graze until they reach 1000 lb. Expected slaughter weights range from 1250-1325 lb for heifers and 1350-1450 lb for steers. Making the above assumptions allows all lots to be treated equally for the analysis.

The expected fed price is based on the CME live cattle futures, CAD $ exchange rate and cash-to-futures basis. Steers have a higher rate of gain than heifers and will therefore reach finished weight faster than heifers. The base weight and sex of each lot was used to estimate the slaughter weight and average daily gain (ADG). The weight gain required (slaughter weight – base weight) was divided by ADG to calculate how many days it would take for the animals in a lot to reach slaughter weight. The days to reach slaughter weight were converted to weeks. The top coverage offered by LPI each Thursday that corresponded with the required weeks till finish weight reached was used as the expected fed price variable. If a lot was estimated to take more than 36 weeks to reach slaughter weight, the top coverage for 36 weeks was used. Thirty-six percent of lots were estimated to reach slaughter weight in more than 36 weeks, 57% of lots were estimated to reach slaughter weight between 29 and 35 weeks, and 8% of lots would reach slaughter weight in 24 to 28 weeks. Table 5-6 shows the assumptions used depending on the base weight and gender of the lot. These assumptions align with those used by Canfax modeling of fed animal profit-loss and break-even calculations.

Table 5-6. Assumptions for Determining Weeks to Reach Slaughter Weight

Steer Lots			Heifer Lots		
Base Weight, lb*	ADG, lb/d	Slaughter Weight, lb	Base Weight, lb*	ADG, lb/d	Slaughter Weight, lb
Under 650	3.25	1350	Under 650	2.75	1250
650-800	3.50	1400	650 - 800	3.00	1300
Over 800	3.60	1450	Over 800	3.15	1325

*Assumptions based on Canfax Market Trends, 2021

5.4 Descriptive Summary of the Data Source

This research utilized a hedonic pricing model to analyze feeder calf attributes for 4,866 lots of calves sold through Western Canadian (BC, AB, and SK) online auctions from 2016 to 2020. There are 3,235 steer calf lots with a base weight of 400 to 800lb and 1,631 heifer calf lots with a base weight of 400 to 800lb. Table 5-7 and 5-8 present some descriptive statistics for the Lot Listing Database. Analysis used a linear hedonic pricing model and OLS regression using StataIC16 for statistical software.

Table 5-7. Descriptive Statistics for Base Weight, Lot Size, Sale Price, Expected Feeder Price, Sale Week and Days to Delivery, 2016 to 2020

		Steer and Heifer Calves, 400 to 800 lb			
Gender	**Mean Variable**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
Steers	Base Weight (lb)	602.86	75.35	400	800
	Lot Size (# of Head)	108.88	60.52	10	625
	Sale Price ($ per cwt.)	$210.32	17.37	$149.00	$275.00
	Expect Fed Price ($ per cwt)	$151.21	10.20	$119.70	$165.90
	Sale Week (# of week)	39.36	3.53	32	51
	Days to Delivery	31.89	19.16	0	161
Heifers	Base Weight (lb)	553.37	69.30	400	800
	Lot Size (# of Head)	93.72	55.21	10	625
	Sale Price ($ per cwt.)	$191.11	16.64	$135.25	$244.00
	Expect Fed Price ($ per cwt)	$151.64	9.99	$121.80	$170.10
	Sale Week (# of week)	39.18	3.32	32	52

Days to Delivery	32.22	17.68	0	139

Table 5-8. Lot Listing Database Means, 2016 to 2020

		Steers 400 to 800lb		Heifers 400 to 800lb	
		Observations		Observations	
Characteristic	**Variable Description**	# of Lots	% of Lots	# of Lots	% of Lots
Weight Variation	Uneven (100-199 lb spread)	2137	66.06%	1111	68.12%
	Even (less than 100 lb spread)	545	16.85%	247	15.14%
	Very Uneven (over 200 lb spread)	553	17.09%	273	16.74%
Frame	Medium	814	7.48%	471	12.51%
	Small to Small-Medium Mix	242	25.16%	204	28.88%
	Medium-Large Mix	2179	67.36%	956	58.61%
Flesh	Medium to Heavy	1712	52.92%	863	52.91%
	Light-Medium Mix	699	21.61%	337	20.66%
	Light	824	25.47%	431	26.43%
Implant	Not Implanted	1342	41.48%	345	21.15%
	Implanted	1150	35.55%	783	48.01%
	Not Specified	743	22.97%	503	30.84%
VBP+ Operation	Not Specified	2983	92.21%	1522	93.32%
	Operation mentioned VBP+	252	7.79%	109	6.68%
Age Verification	Not Specified	1600	49.46%	786	48.19%
	Lot mentions age verification	1635	50.54%	845	51.81%
EU Eligible	Not Specified	3085	95.36%	1565	95.95%
	Lot mentions EU eligibility	150	4.64%	66	4.05%
Weaned	Not weaned	3052	94.34%	1534	94.05%
	Weaned	183	5.66%	97	5.95%
Hide/Coat Colour	Black	1210	37.40%	527	32.31%
	Charolais Influence	326	10.08%	331	20.29%
	Red	581	17.96%	226	13.86%
	Mixed	1118	34.56%	547	33.54%
Location	British Columbia	250	7.73%	139	8.52%
	Alberta	2020	62.44%	1154	70.75%
	Saskatchewan	965	29.83%	338	20.72%

Chapter 6. Estimation of Model

6.1 Model Specifications

The hedonic pricing model used for this research is based on theory presented in Chapter 3, theoretical characteristics discussed in Chapter 4 and insights shared by industry stakeholders. A hedonic model assumes a fixed supply for a particular market; demand for a calf lot is based on individual lot characteristics that influence aggregate beef production (Faminow & Gum, 1986). Vertical market signals travel upstream from beef consumers to primary beef producers, in the form of implicit premiums or discounts for specific calf characteristics (Zimmerman et al., 2012).

Equation (6-1) is the empirical model for this study showing how price is dependent on lot, genetic, management, and market structure characteristics.

$$Price_{it} = f(Lotsize_{it}, Lotsize_{it}^2, Wt_{it}, Wt_{it}^2, Wtvar_{it,} Week_{it,} Frame_{it,} Flesh_{it,} Implant_{it,} VBP_{it,} AV_{it,} EU_{it,} Weaned_{it,} Hide_{it}, Location_{it}, DTD_{it,} Expfedprice_{it}) \tag{6.1}$$

The price of an individual lot of cattle i on auction date t is dependent on the individual lot characteristics and auction day market forces where…

$Lotsize_{it}$ = Number of head in the lot

Wt_{it} = Estimated average weight (lb) per calf in the lot

$Wtvar_{it}$ = Weight variation within lot (Three categorical variables)

$Week_{it}$ = The week number of the year the sale occurred

$Frame_{it}$ = Frame size of the lot (Three categorical variables)

$Flesh_{it}$ = Body condition of the cattle (Three categorical variables)

$Implant_{it}$ = Implant status of lot (Three categorical variables)

VBP_{it} = Lot mentions VBP+ (Binary variable)

AV_{it} = Lot mentions calves are age verified (Binary variable)

EU_{it} = Lot mentions EU eligibility (Binary variable)

$Weaned_{it}$ = If the lot is weaned or preconditioned (Binary variable)

$Hide_{it}$ = Hide color of 80% or greater for the lot (Four categorical variables)

$Location_{it}$ = Location of the calves (Three categorical variables)

DTD_{it} = Number of days between sale date and delivery date

$Expfedprice_{it}$ = Expected fed cattle price, based on Livestock Price Insurance

6.2 Expected Coefficient Signs

Table 6.1 includes the expected coefficient signs for each model variable, the following paragraphs will justify these expectations. Expectations were formed utilizing previous literature and ideas discussed throughout Chapters 2, 3, and 4.

Table 6-1. Expected Coefficient Signs for the Model

Variable Name	Expected Coefficient Sign	Variable Name	Expected Coefficient Sign
Lot Size ($Lotsize_{it}$)	Positive	**VBP+** (VBP_{it})	Positive
Lot Size Squared ($Lotsize_{it}^2$)	Negative	**Age Verified** (AV_{it})	Positive
Base WT (Wt_{it})	Negative	**EU** (EU_{it})	Positive
Base WT Squared (Wt_{it}^2)	Positive	**Weaned** ($Weaned_{it}$)	Positive
Weight Variation ($Wtvar_{it}$)	Negative	**Hide Color** ($Hide_{it}$)	Negative
Week ($Week_{it}$)	Negative	**Location** ($Location_{it}$)	Positive
Frame Size ($Frame_{it}$)	Negative	**Days to Delivery** (DTD_{it})	Positive
Flesh ($Flesh_{it}$)	Negative	**Expected Fed Price** ($Expfedprice_{it}$)	Positive
Implant Status ($Implant_{it}$)	Positive		

As the lot size (number of head) increases, buyers' willingness to pay for a larger lot with more calves should also increase, therefore for every additional animal added to the lot, price is expected to increase. There should be an optimum number of head per lot identified within the model where prices are the highest; once the number of head exceeds the optimum size prices begin to decline. The lot size squared variable is included because lot size has been found to have a non-linear influence on price (Faminow & Gum, 1986; Schroeder et al., 1988; Zimmerman, 2010); lot size positively affects price at a decreasing rate. As the average weight of the calves in a lot increases, price is expected to decrease. Menzie et al. (1972) found that weight had a negative relationship on price, and that including a weight squared variable allowed for a non-constant weight-price relationship to be analyzed. Lots with more uneven weight variation are expected to have a negative effect on price. Buyers are expected to value lots with even (low) weight spread; the coefficient for "even" lots is expected to be positive.

The week number for each lot has been included as a model variable to capture the price change of feeder calves as the year progresses. Price seasonality charts (Figure 2.1) show calf prices tend to drop as the year progresses as market volumes increase. It is expected that the week variable will have a negative coefficient sign, calves marketed in late August to early September will receive higher prices than those sold later in the year. Justification for this expectation is that from the data, it is observed that more calves are sold via online auction early before the influx of calves are marketed via live auction and the market is oversupplied, suppressing prices.

Increasing frame size is expected to have a negative effect on price, larger framed animals are often bigger and heavier in weight. The expected sign for weight is negative and increasing frame size is related to heavier weight. Increasing flesh from light to heavy is expected to have a negative effect on price. Fleshier calves have shown to be discounted due to having more fat or body weight (Bulut & Lawrence, 2007; Seeger et al., 2011). The expected sign for the implant variable will be positive if buyers value calves that have been implanted. Lots where implant status is "Not Specified", are expected to have a negative coefficient. If buyers value calves from VBP+ operations, the expected coefficient sign will be positive, buyers who are VBP+ certified operations may want to source VBP+ raised calves in order to capture the retroactive credit paid by Cargill. Age verification is expected to have a positive effect on price; if buyers value the additional marketing opportunities that come with meeting export age requirements. The EU mention variable is expected to have a positive coefficient sign buyers value calves eligible for EU export. The weaned variable is expected to have a positive effect on price because weaned calves should be over the stress of weaning with less chance of illness and acclimated to drinking from a water bowl and eating from a bunk.

It is expected that hide colour will influence price. During discovery conversations with industry representatives Charolais influenced cattle (tan, white, or silver) were stated to be sought by buyers followed by black and red hided cattle. Lots with mixed hide colours are expected to be discounted in the market due to non-uniform visual appearance of the lots, these lots may also be a combination of multiple breeds.

The location variable is expected to have a positive coefficient sign for Alberta and Saskatchewan when compared to the base (British Columbia); buyers are expected to be willing to pay more for calves in closer proximity to southern Alberta's highly concentrated feedlot sector and three federally inspected packing plants. As days to delivery increase price is expected to increase, the longer the days to delivery the less time the buyers will be in possession and incurring feeding costs for the calves. The expected fed price is expected to have a positive effect on price, as the expected price of fed animals increases buyers' willingness to pay for calves will also increase.

6.3 Collinearity Test

Collinearity occurs when independent variables in a regression model are correlated (Wooldridge, 2012). One popular method to determine if multicollinearity is present and potentially causing skewed results is the Variance Inflation Factor (VIFs).

VIFs use multiple regression to calculate the degree of multicollinearity, the data analysis software uses multiple regression to regress all independent variables (IVs) except one on that final IV, this process is repeated for all IVs and produces the VIF value. When VIFs are calculated all IVs become a dependent variable, and the R-squared value for the model is used. In this case a higher R-squared value is a sign of higher degrees of multicollinearity. The following equation (6.2) is how the VIFs for independent variables are calculated:

$$VIF_i = \frac{1}{1 - R_i^2} \tag{6.2}$$

Where i indicates the independent variables, each IV has a VIF. When the R-squared value is zero there is no multicollinearity because the set of IVs does not explain any of the variability in the IV in question. The lowest VIF value is one, indicating that no multicollinearity exists. The higher the VIF value the more multicollinearity is present (Wooldridge, 2012). Using StataIC 16, the VIFs can be calculated using code "vif" which yields VIF values for each independent variable in the model. The statistical rules vary for VIF threshold value where multicollinearity becomes a concern. This research follows work supported by James et al. (2014), where VIF values exceeding ten will be further examined for multicollinearity. All models will be tested using the VIF method, and any VIF values greater than ten will be disclosed. Appendix D provides a table of VIF values for all independent model variables.

6.4 Testing for Heteroscedasticity

Heteroscedasticity can be common in time-series and cross-sectional datasets where estimates have a non-constant variance. OLS regression assumes that the regression estimates errors have a constant variance, this is known as homoscedasticity (Wooldridge, 2012). If this assumption is not met and models exhibit heteroscedasticity, the estimates determined through OLS regression are unbiased, but inefficient due to the non-constant variance. When heteroscedasticity is present, the P-values calculated using the biased standard errors are inaccurate.

Models will be tested for the presence of heteroscedasticity utilizing the White Test. This test regresses the squared residuals on all dependent variables, their squares, and their cross-products. The White Test can be performed after the regression model in StataIC 16 using the code "estat imtest, white". The White Test provides the null hypothesis that homoscedasticity is present and an alternative hypothesis that unrestricted heteroscedasticity is present. If test results are significant at less than a 95 percent confidence level, then the OLS estimated standard errors can be used. If the test result confidence level is 95 percent or greater the model will have to be regressed using robust standard errors. To regress the model using robust standard errors in StataIC 16 the code "vce(robust)" can be included at the end of the OLS regression. Each model will include the test results. If heteroscedasticity is present, the model will be regressed using robust standard errors to calculate the P-value for the regression results.

Chapter 7. Results

7.1 Introduction

This chapter provides the empirical results for the hedonic pricing model for feeder calves sold via online auction from 2016 to 2020. Results include six models each for steers and heifers weighing between 400 to 800 lb; five annual models and one pooled model for all five years for each sex. The models estimated coefficients for 17 independent variables based on 1,631 heifer calf lots and 3,235 steer calf lots. All results are reported in Canadian dollars per hundredweight. Table 7.1 shows the means for the pooled (2016 to 2020) hedonic pricing model and Table 7.2 presents the estimated coefficients for the pooled model. Table 7.3 reports the mean, standard deviation and range for Average Base Weight, Lot Size, Sale Price, Expected Fed Cattle Price, Sale Week and Days to Delivery by year (2016 to 2020) for annual steer and heifer models. The independent variable means for the annual hedonic pricing models are reported in Table 7.4 and 7.5 for steers and heifers, respectively. Table 7.6 presents the coefficient estimates for the annual steer calf models, and Table 7.7 presents the coefficient estimates for the annual heifer models.

Results are organized based on Chapter 5: Description of Model Characteristics, both steer and heifer results for all years of the model will be discussed together. Only estimates significant at the 95% confidence level or greater will be discussed.

Table 7-1. Means for Pooled Hedonic Pricing Model, 2016 to 2020

Characteristic	Variable Description	Steers - 400 to 800lb Observations # of Lots	Steers - 400 to 800lb Observations % of Lots	Heifers - 400 to 800lb Observations # of Lots	Heifers - 400 to 800lb Observations % of Lots
2016	Binary variable for year	556	17.19%	289	17.72%
2017	Binary variable for year	603	18.64%	297	18.21%
2018	Binary variable for year	637	19.69%	347	21.28%
2019	Binary variable for year	706	21.82%	339	20.78%
2020	Binary variable for year	733	22.66%	359	22.01%
Weight Variation	Uneven (101 – 199 lb spread)	2137	66.06%	1111	68.12%
	Even (less than 100 lb spread)	545	16.85%	247	15.14%
	Very Uneven (over 200 lb spread)	814	7.48%	471	12.51%
Frame	Medium	242	25.16%	204	28.88%
	Small to Small-Medium Mix	238	7.36%	198	12.14%
	Medium-Large Mix	2166	66.96%	943	57.82%
Flesh	Medium to Heavy	1712	52.92%	863	52.91%
	Light-Medium Mix	699	21.61%	337	20.66%
	Light	824	25.47%	431	26.43%
Implant	Not Implanted	1342	41.48%	345	21.15%
	Implanted	1150	35.55%	783	48.01%
	Not Specified	743	22.97%	503	30.84%
VBP+ Operation	Not Specified	2983	92.21%	1522	93.32%
	Operation mentioned VBP+	252	7.79%	109	6.68%
Age Verification	Not Specified	1600	49.46%	786	48.19%
	Lot mentions age verification	1635	50.54%	845	51.81%
EU Eligible	Not Specified	3085	95.36%	1565	95.95%
	Lot mentions EU eligibility	150	4.64%	66	4.05%
Weaned	Not weaned	3052	94.34%	1534	94.05%
	Weaned	183	5.66%	97	5.95%
Hide/Coat Colour	Black	1210	37.40%	527	32.31%
	Charolais Influence	326	10.08%	331	20.29%
	Red	581	17.96%	226	13.86%
	Mixed	1118	34.56%	547	33.54%
Location	British Columbia	250	7.73%	139	8.52%
	Alberta	2020	62.44%	1154	70.75%
	Saskatchewan	965	29.83%	338	20.72%

Table 7-2. Coefficient Estimates for Pooled Hedonic Pricing Models, 2016 to 2020

		Steers - 400 to 800lb			**Heifers - 400 to 800lb**		
Characteristic	**Variable Description**	**Observ. (lots)**	**Coefficient Estimate ($/cwt.)**	**P-Value (P>│t│)**	**Observ. (lots)**	**Coefficient Estimate ($/cwt.)**	**P-Value (P>│t│)**
Intercept	Intercept	3,235	81.1336	**<0.0001**	1631	36.2343	**<0.0001**
2016	Binary variable for year	556	Base		289	Base	
2017	Binary variable for year	603	22.7938	**<0.0001**	297	19.3113	**<0.0001**
2018	Binary variable for year	637	18.5966	**<0.0001**	347	12.5802	**<0.0001**
2019	Binary variable for year	706	11.1667	**<0.0001**	339	3.1731	**0.013**
2020	Binary variable for year	733	14.9659	**<0.0001**	359	9.6594	**<0.0001**
Lot Size	Number of head in a lot	3,235	0.0337	**<0.0001**	1631	0.0487	**<0.0001**
(Lot Size)^2	Number of head in a lot squared	3,235	-0.0001	**<0.0001**	1631	-0.0001	**<0.0001**
Weight	Avg. base weight (lb) of lot	3,235	-0.1144	**<0.0001**	1631	-0.1020	**<0.0001**
(Weight)^2	Avg. base weight (lb) of lot squared	3,235	0.0004	**<0.0001**	1631	0.0004	**<0.0001**
Weight Variation	Uneven (101-199 lb spread)	2137	Base		1111	Base	
	Even (less than 100 lb spread)	545	1.2622	**<0.0001**	247	2.4427	**<0.0001**
	Very Uneven (over 200 lb spread)	553	-2.4598	**<0.0001**	273	-0.6726	0.207
Week	Week number of sale	3,235	-0.2792	**<0.0001**	1631	-0.2470	**0.027**
Frame	Medium	814	Base		471	Base	
	Small to Small-Medium Mix	242	-1.7762	**0.001**	204	-2.2444	**<0.0001**
	Medium-Large Mix	2179	1.0332	**0.001**	956	0.9366	**0.045**
Flesh	Medium to Heavy	1712	Base		863	Base	
	Light-Medium Mix	699	-0.6601	**0.023**	337	-0.6747	0.139
	Light	824	0.2410	0.450	431	0.8333	0.069
Implant	Not Implanted	1342	Base		345	Base	
	Implanted	1150	-0.4966	0.081	783	-0.8592	0.068
	Not Specified	743	-1.6469	**<0.0001**	503	-3.2364	**<0.0001**
VBP+ Operation	Not Specified	2983	Base	**<0.0001**	1522	Base	
	Operation Mentioned VBP+	252	-0.6396	0.129	109	1.1482	0.124
Age Verification	Not Specified	1600	Base		786	Base	
	Lot mentions age verification	1635	0.7853	**0.002**	845	0.3569	0.344
EU Eligible	Not Specified	3085	Base		1565	Base	
	Lot mentions EU eligibility	150	3.0525	**<0.0001**	66	1.3254	0.123
Weaned	Not weaned	3052	Base		1534	Base	
	Weaned	183	-0.2694	0.762	97	-1.3989	0.203
Hide/Coat Colour	Black	1210	Base		527	Base	
	Charolais Influence	326	5.3524	**<0.0001**	331	5.5316	**<0.0001**
	Red	581	-0.3417	0.301	226	0.7131	0.256
	Mixed	1118	-0.8435	**0.003**	547	-0.7045	0.099
Location	British Columbia	250	Base		139	Base	
	Alberta	2020	3.3295	**<0.0001**	1154	1.2706	0.053
	Saskatchewan	965	1.6957	**0.001**	338	-0.6518	0.397
Days to Delivery	Days between sale and delivery date	3235	-0.0800	**<0.0001**	1631	-0.0613	**<0.0001**
Expected Fed Price	Expected fed price as per LPI	3235	0.7502	**<0.0001**	1631	0.9607	**<0.0001**
Analysis of Variance and Homoscedasticity		**R^2 Value:** 0.8625			**R^2 Value:** 0.817		
		Root MSE: 6.4703			**Root MSE:** 6.8867		
		White Test Results: P> Chi2 < 0.0001			**White Test Results:** P> Chi2 < 0.0001		
		DF = 395	Chi-Square = 1313.44		DF = 395	Chi-Square = 660.25	
		Estimated with Robust Standard Errors			Estimated with Robust Standard Errors		

Table 7-3. Average Base Weight, Lot Size, Sale Price, Expected Feeder Cattle Price, Sale Week and Days to Delivery, 2016 to 2020

		Steers – 400 to 800 lb				Heifers – 400 to 800 lb			
Year	**Mean Variable**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
2016	Base Weight (lb)	605.44	71.48	425	800	555.71	68.09	400	800
	Lot Size (# of Head)	107.61	56.80	20	530	92.57	52.76	12	480
	Sale Price ($ per cwt)	$182.80	$11.04	$149.00	$225.50	$165.04	$10.23	$135.25	$201.00
	Expected Fed Price ($ per cwt)	$133.75	$5.79	$119.70	$142.80	$134.70	$5.77	$121.80	$142.80
	Sale Week (# of week)	40.70	3.08	33	48	40.22	2.69	35	48
	Days to Delivery	27.10	16.25	1	76	29.37	15.37	1	67
2017	Base Weight (lb)	602.78	73.68	425	800	554.58	69.56	400	775
	Lot Size (# of Head)	110.59	64.01	15	625	96.24	61.53	15	625
	Sale Price ($ per cwt)	$215.67	$12.12	$191.50	$266.00	$196.91	$11.28	$177.00	$240.25
	Expected Fed Price ($ per cwt)	$146.48	$4.23	$130.20	$161.70	$147.02	$3.20	$134.40	$157.50
	Sale Week (# of week)	38.55	3.41	32	51	38.34	2.89	34	50
	Days to Delivery	33.28	18.10	1	95	33.21	16.00	1	76
2018	Base Weight (lb)	599.48	75.48	400	800	547.03	66.87	400	800
	Lot Size (# of Head)	105.24	59.68	11	570	93.28	56.93	11	500
	Sale Price ($ per cwt)	$222.26	$11.54	$177.50	$275.00	$203.86	$11.25	$164.00	$244.00
	Expected Fed Price ($ per cwt)	$160.23	$4.69	$144.90	$163.80	$160.70	$4.64	$149.10	$163.80
	Sale Week (# of week)	38.36	3.43	32	51	38.53	3.50	32	52
	Days to Delivery	34.86	21.87	1	161	33.14	19.56	1	139
2019	Base Weight (lb)	600.49	77.52	420	800	550.97	69.36	400	800
	Lot Size (# of Head)	110.79	59.60	11	525	96.25	57.28	11	525
	Sale Price ($ per cwt)	$213.43	$10.09	$184.25	$260.00	$192.26	$8.72	$175.00	$235.00
	Expected Fed Price ($ per cwt)	$157.99	$3.10	$138.60	$165.90	$158.22	$2.47	$151.20	$170.10
	Sale Week (# of week)	39.86	3.61	33	51	39.45	3.44	33	50
	Days to Delivery	29.48	19.00	1	122	31.14	17.85	1	95
2020	Base Weight (lb)	606.16	77.31	420	800	558.89	72.04	400	800
	Lot Size (# of Head)	109.75	61.88	10	600	90.59	47.48	10	425
	Sale Price ($ per cwt)	$213.43	$12.84	$180.00	$267.00	$193.90	$11.59	$164.00	$233.00
	Expected Fed Price ($ per cwt)	$153.98	$4.27	$138.60	$159.60	$154.14	$4.07	$138.60	$157.50
	Sale Week (# of week)	39.40	3.51	33	51	39.42	3.53	35	51
	Days to Delivery	34.12	18.73	0	97	33.82	18.42	0	97

Table 7-4. Means for Steer Hedonic Pricing Models, 2016 to 2020

Characteristic	Variable Description	2016 Observations # of Lots	2016 Observations % of Lots	2017 Observations # of Lots	2017 Observations % of Lots	2018 Observations # of Lots	2018 Observations % of Lots	2019 Observations # of Lots	2019 Observations % of Lots	2020 Observations # of Lots	2020 Observations % of Lots
Weight Variation	Uneven (101-199 lb spread)	381	68.53%	372	61.69%	419	65.78%	451	63.88%	514	70.12%
	Even (less than 100 lb spread)	89	16.01%	99	16.42%	103	16.17%	127	17.99%	127	17.33%
	Very Uneven (>200 lb spread)	86	15.47%	132	21.89%	115	18.05%	128	18.13%	92	12.55%
Frame	Medium	164	29.50%	167	27.69%	149	23.39%	168	23.80%	166	22.65%
	Small to Small-Medium Mix	51	9.17%	48	7.96%	30	4.71%	53	7.51%	60	8.19%
	Medium-Large Mix	341	61.33%	388	64.34%	458	71.90%	485	68.70%	507	69.17%
Flesh	Medium to Heavy	289	51.98%	316	52.40%	329	51.65%	399	56.52%	379	51.71%
	Light-Medium Mix	125	22.48%	114	18.91%	141	22.14%	155	21.95%	164	22.37%
	Light	142	25.54%	173	28.69%	167	26.22%	152	21.53%	190	25.92%
Implant	Not Implanted	250	44.96%	226	37.48%	265	41.60%	286	40.51%	315	42.97%
	Implanted	175	31.47%	218	36.15%	237	37.21%	256	36.26%	264	36.02%
	Not Specified	131	23.56%	159	26.37%	135	21.19%	164	23.23%	154	21.01%
VBP+ Operation	Not Specified	536	96.40%	587	97.35%	605	94.98%	635	89.94%	620	84.58%
	Operation mentioned VBP+	20	3.60%	16	2.65%	32	5.02%	71	10.06%	113	15.42%
Age Verification	Not Specified	231	41.55%	295	48.92%	314	49.29%	363	51.42%	397	54.16%
	Lot mentions age verification	325	58.45%	308	51.08%	323	50.71%	343	48.58%	336	45.84%
EU Eligible	Not Specified			599	99.34%	612	96.08%	652	92.35%	666	90.86%
	Lot mentions EU eligibility			4	0.66%	25	3.92%	54	7.65%	67	9.14%
Weaned	Not weaned	548	98.56%	570	94.53%	604	94.82%	649	91.93%	681	92.91%
	Weaned	8	1.44%	33	5.47%	33	5.18%	57	8.07%	52	7.09%
Hide/Coat Colour	Black	200	35.97%	227	37.65%	229	35.95%	268	37.96%	286	39.02%
	Charolais Influence	49	8.81%	65	10.78%	56	8.79%	72	10.20%	84	11.46%
	Red	98	17.63%	107	17.74%	115	18.05%	133	18.84%	128	17.46%
	Mixed	209	37.59%	204	33.83%	237	37.21%	233	33.00%	235	32.06%
Location	British Columbia	39	7.01%	43	7.13%	39	6.12%	62	8.78%	67	9.14%
	Alberta	365	65.65%	388	64.34%	387	60.75%	447	63.31%	433	59.07%
	Saskatchewan	152	27.34%	172	28.52%	211	33.12%	197	27.90%	233	31.79%

Table 7-5. Means for Heifer Hedonic Pricing Models, 2016 to 2020

Characteristic	Variable Description	2016		2017		2018		2019		2020	
		Observations		Observations		Observations		Observations		Observations	
		# of Lots	% of Lots	# of Lots	% of Lots	# of Lots	% of Lots	# of Lots	% of Lots	# of Lots	% of Lots
Weight Variation	Uneven (101-199 lb spread)	198	68.51%	191	21.21%	233	67.15%	223	65.78%	266	74.09%
	Even (less than 100 lb spread)	43	14.88%	43	14.48%	55	15.85%	223	65.78%	48	13.37%
	Very Uneven (>200 lb spread)	48	16.61%	63	21.21%	59	17.00%	58	17.11%	45	12.53%
Frame	Medium	89	30.80%	104	35.02%	87	25.07%	100	29.50%	91	25.35%
	Small to Small-Medium Mix	49	16.96%	33	11.11%	36	10.37%	41	12.09%	45	12.53%
	Medium-Large Mix	151	52.25%	160	53.87%	224	64.55%	198	58.41%	223	62.12%
Flesh	Medium to Heavy	152	52.60%	161	54.21%	182	52.45%	188	55.46%	180	50.14%
	Light-Medium Mix	54	18.69%	58	19.53%	74	21.33%	68	20.06%	83	23.12%
	Light	83	28.72%	78	26.26%	91	26.22%	83	24.48%	96	26.74%
Implant	Not Implanted	50	17.30%	49	16.50%	70	20.17%	83	24.48%	93	25.91%
	Implanted	133	46.02%	154	51.85%	187	53.89%	149	43.95%	160	44.57%
	Not Specified	106	36.68%	94	31.65%	90	25.94%	107	31.56%	106	29.53%
VBP+ Operation	Not Specified	280	96.89%	291	97.98%	330	95.10%	309	91.15%	312	86.91%
	Operation mentioned VBP+	280	96.89%	291	97.98%	330	95.10%	309	91.15%	312	86.91%
Age Verification	Not Specified	9	3.11%	6	2.02%	17	4.90%	30	8.85%	47	13.09%
	Lot mentions age verification	168	58.13%	155	52.19%	181	52.16%	176	51.92%	165	45.96%
EU Eligible	Not Specified			294	98.99%	334	96.25%	313	92.33%	335	93.31%
	Lot mentions EU eligibility			3	1.01%	13	3.75%	26	7.67%	24	6.69%
Weaned	Not weaned	283	97.92%	283	95.29%	327	94.24%	312	92.04%	329	91.64%
	Weaned	6	2.08%	14	4.71%	20	5.76%	27	7.96%	30	8.36%
Hide/Coat Colour	Black	91	31.49%	96	32.32%	119	34.29%	108	31.86%	113	31.48%
	Charolais Influence	52	17.99%	59	19.87%	54	15.56%	76	22.42%	90	25.07%
	Red	47	16.26%	45	15.15%	46	13.26%	47	13.86%	41	11.42%
	Mixed	99	34.26%	97	32.66%	128	36.89%	108	31.86%	115	32.03%
Location	British Columbia	26	9.00%	26	8.75%	25	7.20%	33	9.73%	29	8.08%
	Alberta	210	72.66%	214	72.05%	238	68.59%	249	73.45%	243	67.69%
	Saskatchewan	53	18.34%	57	19.19%	84	24.21%	57	16.81%	87	24.23%

Table 7-6. Coefficient Estimates for Annual Steer Hedonic Pricing Models, 2016 to 2020

		2016			2017			2018		
Characteristic	**Variable Description**	**Observ. (lots)**	**Coefficient ($/cwt)**	**P-Value (P>│t│)**	**Observ. (lots)**	**Coefficient ($/cwt)**	**P-Value (P>│t│)**	**Observ. (lots)**	**Coefficient ($/cwt)**	**P-Value (P>│t│)**
Intercept	Intercept	556	52.8222	**<0.0001**	0	191.7837	**<0.0001**	637	151.8101	**<0.0001**
Lot Size	Number of head in a lot	556	0.0396	**<0.0001**	603	0.0341	**<0.0001**	637	0.0302	**<0.0001**
(Lot Size)^2	Number of head in a lot squared	556	-0.0001	**<0.0001**	603	-0.0001	**<0.0001**	637	0.0000	0.406
Weight	Avg. base weight (lb) of lot	556	-0.0917	**<0.0001**	603	-0.1042	**<0.0001**	637	-0.1111	**<0.0001**
(Weight)^2	Avg. base weight (lb) of lot squared	556	0.0004	**<0.0001**	603	0.0004	**<0.0001**	637	0.0004	**<0.0001**
Weight Variation	Uneven (101-199 lb spread)	381	Base		372	Base		419	Base	
	Even (less than 100 lb spread)	89	1.5838	**0.042**	99	1.9610	**<0.0001**	103	2.2866	**0.001**
	Very Uneven (>200 lb spread)	86	-2.3213	**0.001**	132	-2.0368	**0.007**	115	-2.6783	**<0.0001**
Week	Week number of sale	556	-0.3579	0.104	603	1.4113	**<0.0001**	637	-1.0344	**<0.0001**
Frame	Medium	164	Base		167	Base		149	Base	
	Small to Small-Medium Mix	51	-1.5550	0.990	48	-2.2042	**0.018**	30	-1.6342	0.118
	Medium-Large Mix	341	1.5045	0.057	388	2.1915	**<0.0001**	458	1.5271	**0.011**
Flesh	Medium to Heavy	289	Base		316	Base		329	Base	
	Light-Medium Mix	125	-0.2513	0.746	114	-1.3851	**0.034**	141	-0.5469	0.320
	Light	142	0.2092	0.809	173	1.1091	0.083	167	0.0080	0.989
Implant	Not Implanted	250	Base		226	Base		265	Base	
	Implanted	175	0.1338	0.848	218	-0.4363	0.476	237	-1.0388	0.054
	Not Specified	131	-0.9628	0.227	159	-2.1214	**0.001**	135	-1.6634	**0.004**
VBP+ Operation	Not Specified	536	Base		587	Base		605	Base	
	Operation mentioned VBP+	20	-1.7980	0.075	16	-1.8998	0.223	32	-1.4513	0.238
Age Verification	Not Specified	231	Base		295	Base		314	Base	
	Lot mentions age verification	325	0.1265	0.863	308	1.4311	**0.008**	323	1.1063	**0.016**
EU Eligible	Not Specified				4	Base		612	Base	
	Lot mentions EU eligibility				599	-2.3190	0.671	25	1.7501	0.157
Weaned	Not weaned	548	Base		570	Base		604	Base	
	Weaned	8	-1.9862	0.600	33	-7.4814	**0.002**	33	-2.4625	0.163
Hide/Coat Colour	Black	200	Base		227	Base		229	Base	
	Charolais Influence	49	5.6384	**<0.0001**	65	5.8112	**<0.0001**	56	5.3770	**<0.0001**
	Red	98	-0.1769	0.821	107	-0.3296	0.643	115	0.0368	0.955
	Mixed	209	-1.3477	**0.050**	204	-1.4052	**0.016**	237	-1.2718	**0.015**
Location	British Columbia	39	Base		43	Base		39	Base	
	Alberta	365	4.8463	**<0.0001**	388	4.0055	**0.001**	387	2.6953	**0.005**
	Saskatchewan	152	4.1929	**0.001**	172	3.0086	**0.018**	211	1.1105	0.268
Days to Delivery	Days between sale and delivery date	556	-0.0449	0.199	603	-0.1400	**<0.0001**	637	-0.0637	**<0.0001**
Expected Fed Price	Expected fed price as per LPI	556	0.9438	**<0.0001**	603	0.1371	0.080	637	0.4319	**<0.0001**
Analysis of Variance and Homoscedasticity		**R^2 Value:** 0.6544 **Root MSE:** 6.6314 **White Test Results:** P> Chi2 < 0.0001 DF = 255 Chi-Square = 369.98 Estimated with Robust Standard Errors			**R^2 Value:** 0.7757 **Root MSE:** 5.8564 **White Test Results:** P> Chi2 < 0.0001 DF = 270 Chi-Square = 451.28 Estimated with Robust Standard Errors			**R^2 Value:** 0.7873 **Root MSE:** 5.4241 **White Test Results:** P> Chi2 < 0.0001 DF = 292 Chi-Square = 414.25 Estimated with Robust Standard Errors		

Table 7-6. Coefficient Estimates for Annual Steer Hedonic Pricing Models, 2016 to 2020 – Continued

		2019			2020		
Characteristic	**Variable Description**	**Observ. (lots)**	**Coefficient ($/cwt)**	**P-Value (P>|t|)**	**Observ. (lots)**	**Coefficient ($/cwt)**	**P-Value (P>|t|)**
Intercept	Intercept	706	226.5118	**<0.0001**	733	100.2191	**<0.0001**
Lot Size	Number of head in a lot	706	0.0360	**<0.0001**	733	0.0289	**<0.0001**
(Lot Size)^2	Number of head in a lot squared	706	-0.0001	**0.006**	733	-0.0001	**<0.0001**
Weight	Avg. base weight (lb) of lot	706	-0.1086	**<0.0001**	733	-0.1456	**<0.0001**
(Weight)^2	Avg. base weight (lb) of lot squared	706	0.0004	**<0.0001**	733	0.0005	**<0.0001**
Weight Variation	Uneven (101 - 199 lb spread)	451	Base		514	Base	
	Even (less than 100 lb spread)	127	-0.2033	0.723	127	1.1849	**0.017**
	Very Uneven (over 200 lb spread)	128	-2.0399	**<0.0001**	92	-0.4030	0.434
Week	Week number of sale	706	-0.3553	**0.001**	733	-0.5574	**<0.0001**
Frame	Medium	168	Base		166	Base	
	Small to Small-Medium Mix	53	-3.0024	**0.002**	60	-1.0211	0.200
	Medium-Large Mix	485	1.0947	**0.038**	507	0.3466	0.492
Flesh	Medium to Heavy	399	Base		379	Base	
	Light-Medium Mix	155	-1.1792	**0.010**	164	-0.2323	0.590
	Light	152	0.4019	0.483	190	1.0132	**0.021**
Implant	Not Implanted	286	Base		315	Base	
	Implanted	256	-0.3829	0.443	264	-0.3619	0.402
	Not Specified	164	-1.1295	**0.026**	154	-1.2955	**0.003**
VBP+ Operation	Not Specified	635	Base		620	Base	
	Operation mentioned VBP+	71	-0.3120	0.646	113	1.6331	**0.007**
Age Verification	Not Specified	363	Base		397	Base	
	Lot mentions age verification	343	0.8785	**0.039**	336	0.6444	0.095
EU Eligible	Not Specified	54	Base		67	Base	
	Lot mentions EU eligibility	652	3.1058	**<0.0001**	666	1.7177	**0.017**
Weaned	Not weaned	649	Base		681	Base	
	Weaned	57	-1.5591	0.211	52	0.2441	0.829
Hide/Coat Colour	Black	268	Base		286	Base	
	Charolais Influence	72	4.8729	**<0.0001**	84	4.4639	**<0.0001**
	Red	133	-0.3008	0.557	128	-0.2132	0.661
	Mixed	233	-0.9287	**0.036**	235	-0.2751	0.516
Location	British Columbia	62	Base		67	Base	
	Alberta	447	2.1614	**0.005**	433	2.8296	**<0.0001**
	Saskatchewan	197	0.4613	0.573	233	0.6789	0.374
Days to Delivery	Days between sale and delivery date	706	-0.0910	**<0.0001**	733	-0.0520	**0.001**
Expected Fed Price	Expected fed price as per LPI	706	-0.0841	0.189	733	0.7185	**<0.0001**
Analysis of Variance and Homoscedasticity		**R^2 Value:** 0.7690 **Root MSE:** 4.9369 **White Test Results:** P> Chi2 < 0.0001 DF = 295 Chi-Square = 492.85 Estimated with Robust Standard Errors			**R^2 Value:** 0.8787 **Root MSE:** 4.5460 **White Test Results:** P> Chi2 < 0.0001 DF = 296 Chi-Square = 456.57 Estimated with Robust Standard Errors		

Table 7-7. Coefficient Estimates for Annual Heifer Hedonic Pricing Models, 2016 to 2020

Characteristic	Variable Description	2016 Observ. (lots)	2016 Coefficient ($/cwt)	2016 P-Value (P>│t│)	2017 Observ. (lots)	2017 Coefficient ($/cwt)	2017 P-Value (P>│t│)	2018 Observ. (lots)	2018 Coefficient ($/cwt)	2018 P-Value (P>│t│)
Intercept	Intercept	289	7.7352	0.583	297	154.6499	**<0.0001**	347	118.6656	**<0.0001**
Lot Size	Number of head in a lot	289	0.0709	**<0.0001**	297	0.0436	**<0.0001**	347	0.0439	**<0.0001**
(Lot Size)^2	Number of head in a lot squared	289	-0.0002	**<0.0001**	297	-0.0001	**<0.0001**	347	-0.0001	**0.02**
Weight	Avg. base weight (lb) of lot	289	-0.0589	**<0.0001**	297	-0.1090	**<0.0001**	233	-0.1033	**<0.0001**
(Weight)^2	Avg. base weight (lb) of lot squared	289	0.0003	**<0.0001**	297	0.0006	**<0.0001**	55	0.0004	**<0.0001**
Weight Variation	Uneven (101 - 199 lb spread)	198	Base		191	Base		233	Base	
	Even (less than 100 lb spread)	43	1.3338	0.159	43	3.4146	**0.005**	55	3.9105	**<0.0001**
	Very Uneven (over 200 lb spread)	48	-0.5871	0.584	63	-0.8899	0.393	59	-1.5465	0.123
Week	Week number of sale	289	-0.4864	0.107	297	1.4903	**<0.0001**	347	-1.2811	**<0.0001**
Frame	Medium	89	Base		104	Base		87	Base	
	Small to Small-Medium Mix	49	-1.5903	0.148	33	-3.6591	**0.018**	36	-0.6494	0.604
	Medium-Large Mix	151	0.7844	0.436	160	1.6833	0.076	224	1.4315	0.168
Flesh	Medium to Heavy	152	Base		161	Base		182	Base	
	Light-Medium Mix	54	-0.6351	0.558	58	-0.1246	0.909	74	-0.6564	0.47
	Light	83	1.2117	0.217	78	2.4924	**0.017**	91	0.2059	0.828
Implant	Not Implanted	50	Base		49	Base		70	Base	
	Implanted	133	0.4624	0.642	154	-1.4919	0.22	187	0.1003	0.909
	Not Specified	106	-0.8464	0.465	94	-3.8444	**0.007**	90	-2.8140	**0.007**
VBP+ Operation	Not Specified	280	Base		291	Base		330	Base	
	Operation mentioned VBP+	9	-1.0992	0.483	6	2.3883	0.391	17	-1.4387	0.533
Age Verification	Not Specified	121	Base		142	Base		166	Base	
	Lot mentions age verification	168	1.8576	0.064	155	0.1807	0.851	181	0.0271	0.969
EU Eligible	Not Specified				294	Base		334	Base	
	Lot mentions EU eligibility				3	-1.6805	0.677	13	0.7819	0.613
Weaned	Not weaned	283	Base		283	Base		327	Base	
	Weaned	6	-1.4842	0.663	14	-16.5382	**<0.0001**	20	2.5772	0.387
Hide/Coat Colour	Black	91	Base		96	Base		119	Base	
	Charolais Influence	52	4.9476	**<0.0001**	59	5.5573	**<0.0001**	54	5.0877	**<0.0001**
	Red	47	0.1548	0.884	45	2.0241	0.108	46	0.8510	0.576
	Mixed	99	-0.5804	0.524	97	0.1017	0.921	128	-0.5985	0.462
Location	British Columbia	26	Base		26	Base		25	Base	
	Alberta	210	4.1719	**0.001**	214	1.5798	0.289	238	-0.2254	0.857
	Saskatchewan	53	2.4413	0.111	57	0.4188	0.805	84	-3.2775	**0.031**
Days to Delivery	Days between sale and delivery date	289	-0.0720	0.063	297	-0.0878	**0.017**	347	-0.0748	**0.01**
Expected Fed Price	Expected fed price as per LPI	289	1.1494	**<0.0001**	297	0.2662	**0.036**	347	0.5421	**<0.0001**
Analysis of Variance and Homoscedasticity		**R^2 Value:** 0.6963 **Root MSE:** 5.8763 **White Test Results:** P> Chi2 =0.4306 DF = 242	Chi-Square = 245.20 Estimated with Robust Standard Errors		**R^2 Value:** 0.6654 **Root MSE:** 6.5247 **White Test Results:** P> Chi2 = 0.5223 DF = 248	Chi-Square = 246.09 Estimated with Robust Standard Errors		**R^2 Value:** 0.6891 **Root MSE:** 6.5053 **White Test Results:** P> Chi2 = 0.043 DF = 269	Chi-Square = 310.81 Estimated with Robust Standard Errors	

Table 7-7. Coefficient Estimates for Annual Heifer Hedonic Pricing Models, 2016 to 2020 – Continued

		2019			2020		
Characteristic	**Variable Description**	**Observ. (lots)**	**Coefficient ($/cwt.)**	**P-Value (P>│t│)**	**Observ. (lots)**	**Coefficient ($/cwt.)**	**P-Value (P>│t│)**
Intercept	Intercept	339	212.2695	**<0.0001**	359	65.4238	**0.001**
Lot Size	Number of head in a lot	339	0.0389	**<0.0001**	359	0.0556	**<0.0001**
(Lot Size)^2	Number of head in a lot squared	339	-0.0001	**0.08**	359	-0.0002	**0.001**
Weight	Avg. base weight (lb) of lot	339	-0.0917	**<0.0001**	359	-0.1288	**<0.0001**
(Weight)^2	Avg. base weight (lb) of lot squared	339	0.0003	**<0.0001**	359	0.0004	**<0.0001**
Weight Variation	Uneven (101 - 199 lb spread)	223	Base		266	Base	
	Even (less than 100 lb spread)	223	0.8480	0.308	48	2.4404	0.065
	Very Uneven (over 200 lb spread)	58	-0.2802	0.774	45	2.1863	0.124
Week	Week number of sale	58	-0.0625	0.71	359	-0.3666	0.131
Frame	Medium	100	Base		91	Base	
	Small to Small-Medium Mix	41	-2.7658	**0.005**	45	-0.1590	0.904
	Medium-Large Mix	198	1.3064	0.146	223	0.6501	0.52
Flesh	Medium to Heavy	188	Base		180	Base	
	Light-Medium Mix	68	-0.0282	0.975	83	-2.1932	**0.006**
	Light	83	0.6621	0.49	96	0.5969	0.503
Implant	Not Implanted	83	Base		93	Base	
	Implanted	149	-1.1081	0.23	160	-1.2808	0.153
	Not Specified	107	-1.7622	0.085	106	-3.1184	**0.002**
VBP+ Operation	Not Specified	309	Base		312	Base	
	Operation mentioned VBP+	30	1.2221	0.312	47	1.5343	0.225
Age Verification	Not Specified	163	Base		194	Base	
	Lot mentions age verification	176	0.9109	0.205	165	-0.2688	0.725
EU Eligible	Not Specified	313	Base		335	Base	
	Lot mentions EU eligibility	26	0.0172	0.989	24	3.3139	**0.034**
Weaned	Not weaned	312	Base		329	Base	
	Weaned	27	-3.9038	**0.003**	30	0.2449	0.906
Hide/Coat Colour	Black	108	Base		113	Base	
	Charolais Influence	76	6.9928	**<0.0001**	90	5.8501	**<0.0001**
	Red	47	1.7568	0.172	41	0.7485	0.599
	Mixed	108	-0.4859	0.501	115	-1.4051	0.102
Location	British Columbia	33	Base		29	Base	
	Alberta	249	2.3674	0.13	243	0.6497	0.632
	Saskatchewan	57	1.1963	0.332	87	-0.6787	0.641
Days to Delivery	Days between sale date and delivery date	339	-0.0390	0.183	359	-0.0340	0.252
Expected Fed Price	Expected fed price as per LPI	339	-0.1506	0.294	359	0.8382	**<0.0001**
Analysis of Variance and Homoscedasticity		**R^2 Value:** 0.5916 **Root MSE:** 5.7813 **White Test Results:** P> Chi2 =0.2366 DF = 293 Chi-Square = 310.02 Estimated with Robust Standard Errors			**R^2 Value:** 0.7107 **Root MSE:** 6.4517 **White Test Results:** P> Chi2 = 0.1515 DF = 295 Chi-Square = 320.04 Estimated with Robust Standard Errors		

7.2 Lot Characteristics

As outlined in Chapter 5, section 5.4.1 attributes included as independent variables related to lot characteristics are province of origin and lot size. Annual models have been used for 2016 to 2020 to capture fluctuations and market changes for feeder calves over time. Separate models for steers and heifers were used to identify how the market values attributes individually based on sex of the lot. Model results will be discussed and presented based on year and gender.

Year is included as an independent categorical variable in the pooled models to estimate how the market for feeder calves varied from 2016 (base year). The estimated pooled model for steer calves explained 86 percent of variation in market price over the five years, and 81 percent of price variation for the estimated pooled heifer model. As Figure 7.1 shows, 2016 had the lowest prices for 600lb steers and heifers from August through December, while 2018 had the highest prices. All coefficients estimated for the year variable are significant at the 95% level. The highest coefficients were estimated for both steer and heifer calves in 2017 when compared to the base year 2016; the estimate for steers was $22.79 per cwt and $19.31 per cwt for heifers. The year coefficient was lowest in 2019 $11.17 per cwt for steer calves and $3.17 per cwt for heifer calves.

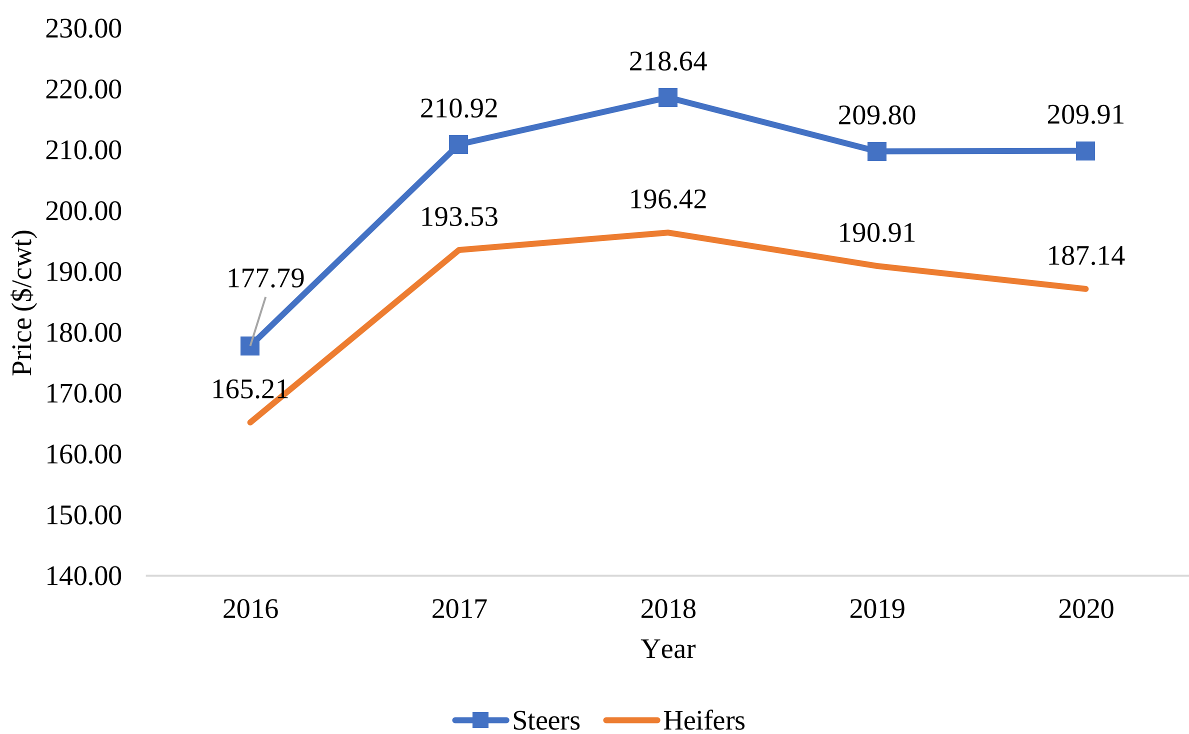

Figure 7-1. Average Yearly Price for 600lb Steer and Heifer Calves, 2016 to 2020

The location estimate was significant in three heifer models and all steer models. With British Columbia (BC) as the base, steer calves located in Alberta (AB) received estimated premiums ranging from $2.16 per cwt in 2019 to $4.85 per cwt in 2016. Steer calves located in Saskatchewan (SK) received a premium in 2016 of $4.19 per cwt and in 2017 $3.01 per cwt. The heifer models yielded premiums for calves located in AB in 2016 ($4.17 per cwt). Heifer calves located in SK received a discount in 2018 of $3.28 per cwt. For the pooled models steer calves located in AB and SK received premiums of $3.33 per cwt, and $1.70 per cwt, respectively. There are no other studies to compare the location price estimates with, as Carlberg and Hogan (2013) only observed two Alberta live auction markets. In much of the existing US research location has been a significant factor influencing price. Research compared prices received on video auctions for different regions of cattle production throughout the US, but these estimates are not comparable to Canada (Blank et al., 2009; McCabe, 2018).

Lot size is an important attribute, as the number of head in a lot influences the price of feeder calves at the 99% confidence level in all models. For all lots included in the data the average lot size is 104 head (SD:59); the minimum lot size is 10 head and the maximum 625 head. For all models, as the number of head in a lot (lot size) increases price increases, but at a decreasing rate. This relationship is the reason for including the “lot size squared” variable which has a negative coefficient sign to represent the discount applied to each additional animal added to the lot once the optimum number of head for a lot is reached. The values for lot size are centered at the mean (mean values: 109 head for steers, and 94 head for heifers). The optimum number of head for a lot of steer calves ranges from 319 to 369, with the exception of 2018 having an optimum lot size of 649 head (Figure 7.2). Upon review of the lot size data for 2018, there was no plausible explanation identified for the anomaly in 2018. The optimum number of head for a lot of heifer calves ranges from 254 to 384 over the five years (Figure 7.3). Optimum lot size was calculated using the number of head per lot, lot size and lot size squared coefficients, to identify at what lot size do prices start to decline, this is graphically represented in Figure 7.2 and 7.3. Intuitively the optimum lot size identified is consistent with the size of typical feedlot pens (250 to 300 head), buyers may be willing to pay a premium for uniform calves from one operation that can be fed and managed together at the feedlot. Premiums for steer calves range from $0.029 per cwt to $0.040 per cwt for every one-head increase in lot size from the mean, and for heifers’ premiums range from $0.039

per cwt to $0.071 per cwt. For both steers and heifer calves, the highest premiums for lot size were in 2016. Schroeder et al. (1988) identified a maximum premium was paid for lightweight cattle sold in lots of 45 to 50 head, and for heavier cattle in lot size of 55 to 65 head. Bulut and Lawrence (2007) found that the maximum price was paid for 77 head in a lot. Premiums of USD$0.33 per cwt were found for each additional head, until 77 head was reached. These results are comparable to research by Seeger et al. (2011) where the mean number of calves in a lot was 95 and premiums ranged from USD$0.0035 per cwt to $0.0179 per cwt for each one-calf increase in lot size. In the Zimmerman (2010) model for 2008 to 2009, steer calves received a premium of USD$0.0127 per cwt for the lot size variable and heifers received a premium of $0.0115 per cwt and the optimum lot size for steers was 575 head. Carlberg and Hogan (2013) found a premium for both locations for a one-head increase in calf lots, premiums were CAD$0.49 per cwt and $0.68 per cwt. McCabe (2018) found a premium of USD$0.0188 per cwt for the lot size variable for the steer model, and a premium of $0.0221 per cwt for heifer calves.

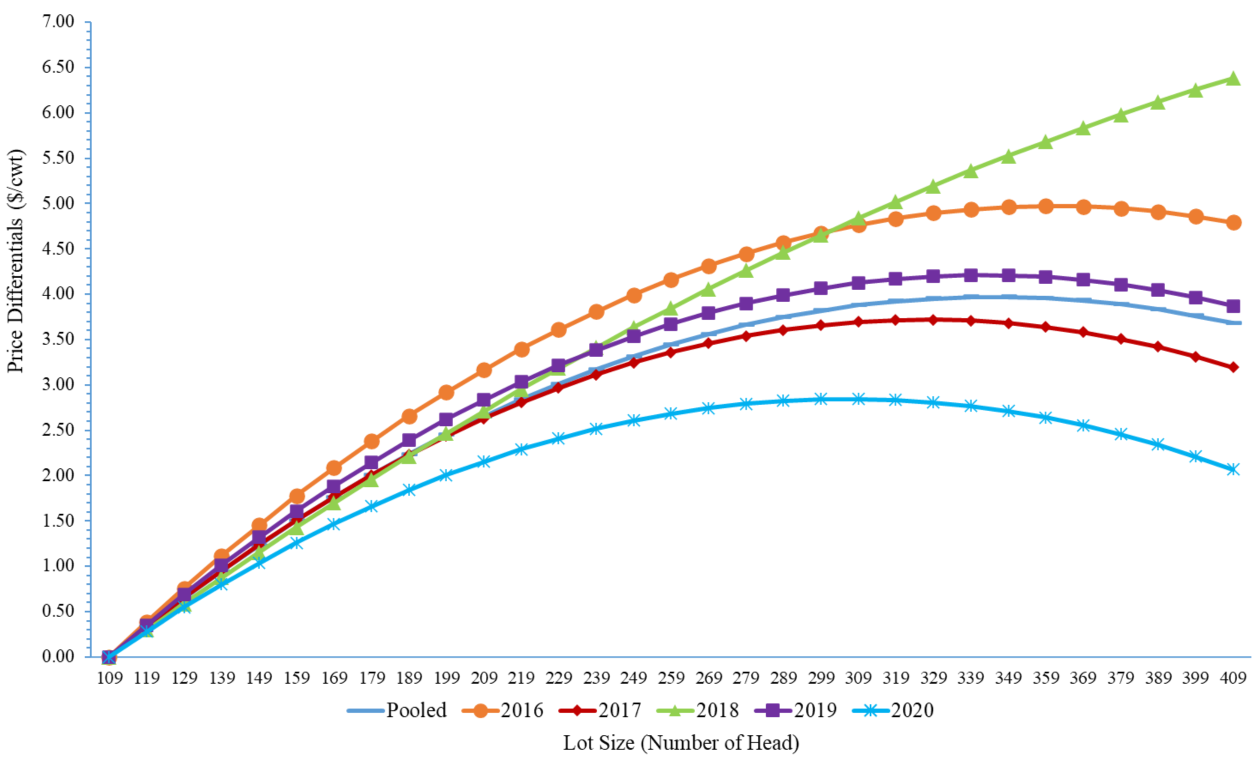

Figure 7-2. Steer Price-Lot Size Relationship, 2016 to 2020

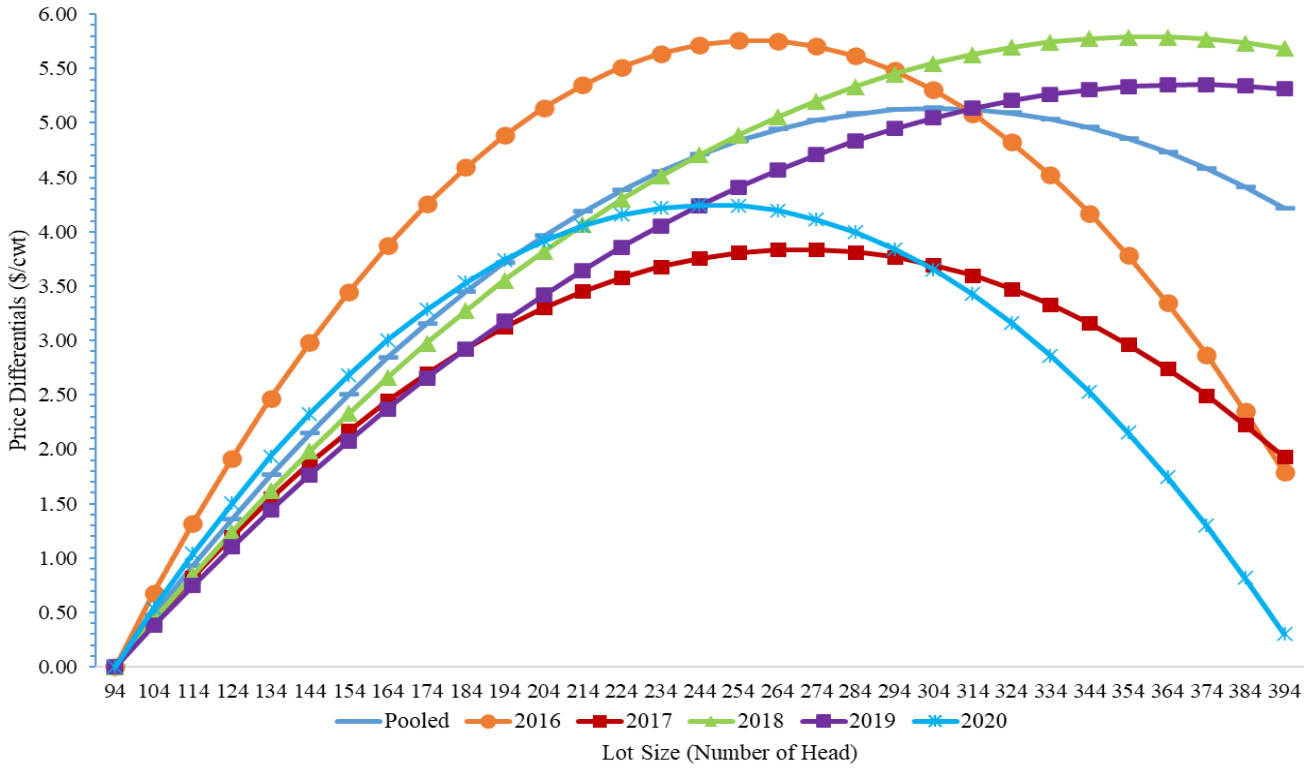

Figure 7-3. Heifer Price-Lot Size Relationship, 2016 to 2020

7.3 Results for Genetic Characteristics

Genetic characteristics of a lot are represented by the frame size and hide colour variable in the model. In both steer and heifer models small-to-medium framed calves received discounts compared to medium framed (base) calves, and medium-to-large-framed calves received premiums. This result differs from the expectation discussed in Chapter 6, it was expected that larger framed animals would be discounted due to being heavier in weight, this expectation was not supported by the model results. A possible explanation is that buyers value larger framed calves because they have the potential to gain more weight when they are put on feed, previous literature also supports that larger framed animals receive premiums. Estimates for medium to large framed steers were significant in three out of five annual models with premiums ranging from $1.09 per cwt to $2.19 per cwt. In the 2017 and 2019 heifer annual models and the pooled model discounts ranged from \$3.66 per cwt. to \$2.24 per cwt for small-to-medium framed calves. In the 2017, 2019 and pooled steer model calves with small-to-medium frame size were discounted, discounts ranged from \$3.00 per cwt to \$1.78 per cwt. These results are comparable with research by Bailey et al. (1993 and 1995), where they found larger framed calves brought premiums of USD \$0.64 per cwt more than small-framed calves in 1993. In 1995, premiums were greater and calves described as medium-to-large framed brought \$3.42 per cwt to \$5.28 per cwt more. Schulz et al. (2010) found a modest premium of USD \$0.75 per cwt given to large-framed calves. Schulz et al. (2015) included a variable to represent frame size, and found medium-to-large, framed calves received premiums of USD\$5.09 per cwt compared to medium framed calves.

Hide colour is a genetic characteristic of calves influenced by breed. It is apparent that Charolais influenced cattle are highly valued and sought after in the market with every model yielding premiums at the 99% significance level. When compared to the base hide colour of black, Charolais influenced cattle received premiums in all annual models ranging from \$4.46 per cwt to \$5.81 per cwt for steer calves and \$4.95 per cwt to \$6.99 per cwt for heifer calves. No other hide colour variable was significant for the heifer models. For the steer models the mixed hide colour variable showed statistically significant discounts for five out of six models ranging from \$0.84 to \$1.41 per cwt. Having Charolais coloured (tan, white, or silver) cattle yield premiums is consistent with discussions had with industry representatives, who stated that white, tan and silver-coloured calves were sought after in the feeder calf market. Only 10% of the steer lots and 20% of the heifer lots were Charolais-influence. It is important to note that multiple breeds are represented in the hide colour variables.

Schulz et al. (2010) included a hide colour variable and found that premiums of USD\$2.49 per cwt. were paid for black cattle, and \$1.01 per cwt for white cattle compared to the base of red hided cattle. Zimmerman et al. (2012) found significant premiums for black and Black Angus calves; premiums ranged from USD\$2.82 per cwt to \$7.03 per cwt when compared to Brahman influenced calves. Premiums were also paid for black or black-white faced calves, \$0.30 per cwt to \$0.90 per cwt for steers and \$0.30 per cwt to \$1.70 per cwt for heifers. Carlberg and Hogan (2013) included a British breed variable in their model; at Location A British breed calves received a premium of CAD\$4.07 per cwt. A variable for black animals was also included in the model and provided significance at Location B with a discount of \$2.84 per cwt for calves. Schulz et al. (2015)

found for preconditioned sales that all other hide colours yield discounts in the market compared to black cattle. Large discounts were estimated for red and white cattle USD$4.49 per cwt and for yellow and/or white were $2.68 per cwt.

Significant results for breed and hide colour were presented by McCabe (2018). Results show steer calves sired by Charolais bulls brought USD$1.23 per cwt more than calves sired by Red Angus bulls ($179.09 per cwt vs $177.86 per cwt). Brahman influenced steer calves had the lowest sale price at $170.97 per cwt. Results show buyers value steer calves sired by Charolais bulls the most, followed by Red and Black Angus sired lots. Red Angus sired heifer calves had the highest estimated sale price at $173.88 per cwt. Heifer calf lots sired by Charolais and Black Angus bulls sold for similar prices of approximately $168.20 per cwt. Similar to steer calves, Brahman influenced heifer calves had the lowest sale price of $162.78 per cwt. Premiums associated with Charolais influenced calves are consistent with results from the current study.

Overall results of this study for hide colour appear to be inconsistent with previous research, as black hided animals did not receive premiums in the market. In the US, premiums for black hided cattle may be due to association with the Angus breed. Buyers may be willing to pay more for Angus calves because they can market them into certified Angus beef programs. It is important to note that the majority of previously discussed results are from US auction data, and buyers' preferences may differ in Canada. Ideally the model in the current study would have included both breed and hide colour as independent variables, however lot listing details did not always provide the percentage of each breed for a given lot.

7.4 Results for Management Characteristics

Management characteristics are those that producers have influence over such as base weight, weight variation, fleshiness, implant status and weaning status.

For all models, the weight variable had a negative statistically significant ($p<0.0001$) coefficient sign. As the base weight of a lot increases the price of the lot will decrease. Base weight was centered to the mean, mean weights were 603lb and 553lb for steers and heifers, respectively. This coefficient can be interpreted as the discount in price received for a one-pound increase in the base weight of the lot from the mean. Discounts ranged from $0.09 per cwt to $0.15 per cwt for steer calves and $0.06 per cwt to $0.13 per cwt for heifer calves. Results are consistent with previous studies and expectations from Chapter 6, as the relationship between price and weight has been analyzed in multiple models for price determinants for feeder calves. Previous research supports the non-linear price-weight relationship that exists for both steers and heifers. Schroeder et al. (1988) found calf prices to be discounted USD$0.198 per cwt when estimating the weight variable and Bulut and Lawrence (2007) found discounts of USD$0.15 per cwt. Blank et al. (2009) estimated a USD$0.098 per cwt discount for the weight variable. Zimmerman (2010) found discounts in the 2008 to 2009 model of USD$0.38 per cwt for steers and $0.31 per cwt, for heifers. Carlberg and Hogan (2013) found a discount for the weight variable for the calf models to be CAD$0.14 per cwt at Location A and $0.19 per cwt at Location B.

Results show that weight variation within a lot is a significant attribute buyers consider when purchasing lots of feeder calves. It is observed that when compared to the base of uneven weight variation, lots with even weight variation receive significant premiums and lots with very uneven weight variation are discounted. Premiums for lots with even (less than 100lb weight spread) weight variation ranged from $1.26 to $2.29 per cwt for steers and $2.44 to $3.91 per cwt for heifers. Discounts for steer calves with very uneven weight variation are large, ranging from $2.04 to $2.68 per cwt.

Schulz et al. (2010) reported a discount of USD$2.11 per cwt for nonuniform weight variation in calf lots. Zimmerman (2010) also found premiums associated with even to fairly-even lot variation when compared to uneven; premiums were $0.53 per cwt for steers and $1.35per cwt for heifers. Weight variation was included in McCabe (2018) and found similar results, even lots received a premium of USD $1.50 per cwt for heifers and $1.15 per cwt for steers when compared to very uneven weight variation. Lots with uneven weight variation received a premium compared to very uneven; $0.56 per cwt for steers and $0.07 per cwt for heifers.

Fleshiness of calves is a subjective attribute as each person’s estimate of how much flesh an animal has will vary, it was expected that this variable would have a negative coefficient sign. For the heifer calf models only two years showed significant price influence for the fleshiness variable. When compared to the base (medium-to-heavy flesh) heifer calves in 2017 that were classified as light fleshed received a premium of $2.49 per cwt and in 2020 light-to-medium flesh heifers were discounted $2.19 per cwt. Steer calves classified as light-to-medium flesh also received a discount in the market when compared to medium-to-heavy fleshed, discounts ranged from $0.66 per cwt to $1.39 per cwt. The 2020 model for steers showed a premium of $1.01 per cwt for light fleshed calves. Results are surprising as there is a discount for light-to-medium flesh calves when compared to medium-to-heavy, generally it was expected that buyers prefer calves that are lighter in flesh when starting on feed.

Bulut and Lawrence (2007) estimated a discount of USD$2.37 per cwt for fleshy calves. Zimmerman (2010) also included a fleshiness variable, with only the steer model showing a premium of USD$0.7022 per cwt for light-medium-to-medium mix fleshiness when compared to medium for the 2008 to 2009 model. McCabe (2018) found that medium-to-light fleshed calves received premiums when compared to medium-to-heavy fleshed calves. Premiums for steers with medium to light flesh ranged from USD$2.23 to $2.81 per cwt and premiums for heifers ranged $1.61 to $2.35 per cwt.

Whether or not to implant calves is an important management decision for most cow-calf producers. It is important for producers to know if buyers value the implant status of calves in the market, given the growing demand for implant-free beef by consumers. Results show that calves listed with no specified implant status receive discounts when compared to calves that have not been implanted (base). Discounts for heifer calves with no-specified implant status were statistically significant in four of six models and ranged from $2.81 to $3.85 per cwt. Discounts for no-specified implant status for steer calves were statistically significant in five of six models ranging from $1.13 to $2.12 per cwt. Results are consistent with expectations that the lack of implant information would have a larger price discount for heifers than steers, as heifers may be purchased for breeding purposes so buyers prefer to know if they have received implants.

Zimmerman (2010) found that unknown implant status had a larger discount on steers (USD$1.282 per cwt) than for heifers ($0.765 per cwt) when compared to non-implanted calves. Zimmerman et al. (2012) also reported large discounts for calves with unknown implant status, but implanted calves received a premium when compared with non-implanted calves. Surprisingly in this study implanted heifer calves brought premiums ranging from USD$1.09 to $2.75 per cwt, and heifers with unknown implant status only brought a discount of $1.23 per cwt. in the 2009 model. Discounts for steer calves with unknown implant status ranged from $1.59 to $2.19 per cwt and premiums for implanted steer calves ranged from $0.99 to $1.94 per cwt. McCabe (2018) did not include a variable for unknown implant status, only a binary variable was used, and results showed that implanted heifer calves were discounted USD$0.61 per cwt over the 2010 to 2016 timeframe.

Producers must decide on weaning status of their calves when marketing them for online auction. Often producers will wean calves at the time of delivery, but in some cases, producers pre-wean calves and they are marketed and sold as weaned. Although the overall representation of weaned calves in the dataset is low (6%) over the five-years the percent of calves marketed as weaned increased from one percent to seven percent for steers and two percent to eight percent for heifers. Given the low number of lots marketed as weaned it was not surprising this variable did not produce many results with significance. Only one annual model (2017) showed statistically significant results for steer calves with a discount of $7.48 per cwt for calves that were sold as weaned. Unexpected estimates for the heifer models were found as the discount for weaned heifer calves in 2017 was $16.54 per cwt and $3.90 per cwt in 2019. The discount for 2017 is large, but the coefficient is estimated at the 99% significance level. It is important to note that the annual models have smaller sample sizes and given the data for that year the model estimated this result. It is also possible that discounts for weaned or preconditioned calves exist because there is no standard defining the requirements for producers using the terms “weaned” or “preconditioned”.

Blank et al. (2009) found a significant discount of USD$3.59 per cwt at the 99% confidence level for calves that had not been weaned but found only a $1.29 per cwt premium at the 90% confidence level for calves that had been weaned less than 30 days. This study also included a preconditioned variable which resulted in a premium of $1.37 per cwt for calves that had been preconditioned. Zimmerman et al. (2012) found significant premiums associated with weaned steer and heifer calves in all ten years of the study. Premiums for weaned steer calves ranged from USD$1.88 to $5.42 per cwt and for heifers $1.99 to $5.15 per cwt. Carlberg and Hogan (2013) included a preconditioned variable in their model, which could serve as a proxy for weaned calves, but no statistically significant price effect for preconditioned calves was present in the model.

7.5 Results for Marketing Characteristics

With different value-added opportunities available to cow-calf producers, it is important they have an idea of what type of value is gained from stating calves are EU eligible, age verified and from VBP+ operations. This is the first known Canadian study analyzing the feeder calf price effects for value-added variables over multiple years, and therefore there is little previous research to compare results. The US beef market has done well researching and explaining the value for various value-added programs, but programs differ from those offered in Canada. Further Canadian research should be done in the value-added sector to confirm and expand on these results.

The EU eligible variable was only significant for the heifer models in 2020, resulting in a premium of $3.31 per cwt for heifer lots mentioned as being EU eligible. EU eligibility provided significant premiums for steers in the pooled model ($3.05 per cwt), in 2019 ($3.11 per cwt) and in 2020 ($1.72 per cwt). There are no other Canadian studies utilizing EU eligibility as an independent variable to compare results to. In previous US studies, (Zimmerman, 2010; Seeger et al., 2011) Superior Livestock Auction's natural programs are used as model variables, lots eligible for the natural programs yield premiums, but results are not comparable to Canada. Discussions with industry stakeholders revealed that in some cases premiums ($0.03 to 0.05 per lb) are paid if producers sign an affidavit stating they did not use hormones and/or antibiotics. There is no way to know which lots received additional premiums, but it is important to note that post-sale negotiations may be occurring.

Significant premiums at the 95% significance level for age verified steer calves were estimated for the pooled model ($0.79 per cwt), in 2017 ($1.43 per cwt), in 2018 ($1.11 per cwt) and in 2019 ($0.88 per cwt). No premiums for age verification were present for the heifer models. Age verification premiums for steers declined over the five-years and no premiums were present in 2020. Carlberg and Hogan (2013) found at both live auction markets premiums of CAD$3.93 and $3.23 per cwt for age verified cattle (pooled model) for Location A and B, respectively. It is important to note that this study used data from a different time (2011 to 2012), and this could be a reason results differ as during that time key export markets still had age restrictions in effect. Zimmerman et al. (2012) found consistent premiums for age and source verification for both steer and heifer models over the timeframe of 2005 to 2010, premiums ranged from USD$0.99 to $2.75 per cwt. Blank et al. (2009) analyzed video auction data from 1997 to 2007, where age and source verified calves showed premiums of USD$5.31 per cwt. There is no other recent literature on age verification than what has been previously discussed. The lack of significance for the age verification variable in 2020 may be due to the lifting of age restrictions by export countries as it has been 18 years since the discovery of BSE, attributes that were important 10 or 20 years ago, may not still be important. As noted previously, there was a decline in the percentage of lots mentioning age verification over the 5 years of the study (58% of lots in 2016 down to 46% of lots in 2020).

The model yielded mostly insignificant results for the VBP+ variable; only one annual steer model and no heifer models showed significance for the VBP+ variable. In 2020 the steer model showed a premium of $1.63 per cwt for lots mentioning VBP+. For both steer and heifer models approximately 7% of lots mention VBP+, but over the 5 years the percentage of lots has been increasing (Figure 5-9). It is important to note that these results may not be fully capturing the benefit gained by VBP+ producers. There are many other platforms to market cattle such as live auction or direct sale, and it is probable that VBP+ operations may market through different platforms, as this research only looks at online auction data. VBP+ cattle may be marketed through a more closely coordinated market channel, where buyers are actively seeking this attribute. VBP+ is a Canadian program and no other data from 2016 to 2020 is available to compare these results.

7.6 Results for Market Structure Characteristics

Results show that the market structures such as number of days to delivery, the week the sale occurred, and the expected fed cattle price have a significant influence on the fluctuation of yearly feeder calf prices. The number of days to delivery for both steer and heifer models showed significance, and the conclusion is that buyers discount lots for having a longer time between sale and delivery. Results can be interpreted as the discount for each additional day between sale date and the delivery date for the calves. Four out of five annual steer models and the pooled model showed a significant discount for each additional day buyers had to wait for delivery after the sale occurred, discounts ranged from $0.05 to $0.14 per cwt. Two out of five annual heifer models and the pooled model showed a significant discount for days to delivery, discounts ranged from $0.61 to $0.09 per cwt.

Zimmerman (2010) included a variable for days to delivery and found discounts of USD$0.022 per cwt for steers and $0.03 per cwt for heifers, for each additional day till delivery. The expected coefficient sign for the days to delivery variable discussed in Chapter 6 was positive, results have shown this expectation was incorrect. Initially it was expected that buyers would prefer to have a longer time between sale date and delivery date because they would not have to start feeding the calves right away, the calves would be gaining weight while still in the possession of the seller. Results suggest that buyers would prefer to gain possession of the calves sooner, therefore they are able to start the calves on a feeding ration to reach finished weight as soon as possible.

The week of the sale had a negative effect on price for both steers and heifers except in 2017 where the estimated coefficient had a positive sign. This variable can be interpreted as the price effect caused by every additional week later in the year that the calves are sold. This will identify if producers were able to extract higher market prices for their calves by selling early in the season or waiting till later. Discounts for the week steers were sold ranged from $0.28 to $1.03 per cwt, except for the 2017 model where a premium of $1.41 per cwt was received for each week later that the lot was sold. Discounts for the week heifers were sold ranged from $0.25 to $1.28 per cwt, except for the 2017 model where a premium of $1.49 per cwt was received. It can be observed that sellers marketing calves earlier in the season receive higher prices than those who wait, except for the year 2017. This is the only study using a week variable, as other studies such as Bulut and Lawrence (2007) include dummy variables for the months of November to February. November and December are the only months that will be relevant for comparison. Calves sold in November received a premium of USD$1.74 per cwt. and in December a premium of $0.94 per cwt.

The expected fed price influenced the price received for steer and heifer calves in the models. The coefficient for the expected fed price variable can be interpreted as the price effect of a $1.00 per cwt increase in the expected fed price. The variable for expected fed price showed significant premiums for heifers in four out of five annual models and the pooled model. Premiums ranged from $0.267 to $1.15 per cwt. Three out of five annual models and the pooled model showed premiums ranging from $0.43 to $0.94 per cwt for the expected fed price for steer calves. Bulut and Lawrence (2007) estimated that a USD $1 per cwt increase in the futures price caused a $0.70 per cwt increase in calf prices.

Zimmerman (2010) found similar premiums for steers and heifers for the feeder cattle futures variable, USD $0.79 and $0.76 per cwt, respectively. Schulz et al. (2015) found a $1 increase in feeder cattle futures resulted in a USD $1.097 per cwt, increase in feeder calf price. Carlberg and Hogan (2013) reported opposite effects of futures price on the price of calves; Location A reported a large premium of CAD $2.95 per cwt for every one dollar increase in futures prices, but Location B reported a CAD$0.66 per cwt discount for the futures price variable.

Chapter 8. Discussion and Implications

The objective of this research was to determine how the market values the attributes of feeder calves sold via online auction in Western Canada using a hedonic pricing model and OLS regression. The model results show that price impacts for lot attributes vary over time, but there are some attributes that consistently impact feeder calf prices. The results suggest that lot size, weight and lot uniformity are among the most important factors influencing the sale price of feeder calves. Charolais influenced cattle consistently receive premiums and are highly sought after in the market. Other factors such as the expected fed price, days to delivery, the week the calves are sold, and undisclosed implant status also have a statistically significant influence on the price of calves. It is important to note that over the dataset timeframe the significance and value of premiums and discounts vary.

Lot size and weight are long standing fundamentals of cattle prices. These attributes are statistically significant in all models and are not subjective variables such as frame and flesh. Coefficients for these variables are easily comparable with US research, and results are consistent with the previous literature that increasing lot size has a positive effect on price, but at a decreasing rate, and the price/weight relationship is non-linear. Buyers value larger, uniform lots of calves, therefore producers who market cattle in larger groups that align with total weight of transportation for cattle liners should receive higher prices.

Producers who do not report the implant status of calves on lot listing reports are at a disadvantage and are receiving price discounts compared to those that report implant status. Results show there are no significant discounts associated with calves that have been implanted. It can be stated that a producer's decision to implant is not a factor influencing price. Zimmerman (2010) presented a similar conclusion; implanted calves were not penalized in the market when compared to non-implanted calves. Therefore, producers should report implant status to avoid the discounts associated with unspecified implant status.

Calves that were sold as weaned received significant discounts, these results are inconsistent with previous US research showing premiums associated with calves sold as weaned. Bulut and Lawrence (2007) and Zimmerman et al. (2012) analyzed weaning and vaccination status to determine the individual price effects associated with each, as well as compared third-party certification with uncertified weaning and vaccination claims. Bulut and Lawrence (2007) found a significant increase in premiums for calves with certified weaning and vaccination claims. They also found premiums associated with calves that were weaned and not vaccinated, this claim may be comparable to the one analyzed in this thesis as the weaned variable does not account for vaccination status. Zimmerman et al. (2012) included a separate variable for weaned status and found significant premiums for steer and heifer lots that were weaned at the time of the sale. The discounts associated with calves marketed as weaned in this study may be attributed to lack of information on claims, such as the number of days they have been weaned or weaning/preconditioning protocol. Buyers may lack confidence in the validity of claims made, or view purchasing calves that have been weaned for an unknown number of days as having a higher risk of morbidity or sickness once entering the feedlot due to the prior stress of weaning. It is important to note that many weaned calves may also be weaned and backgrounded before they are marketed for sale, therefore the timeframe of August to December may not be capturing many weaned calf lots. Implications of these results suggest that claims made around weaning, preconditioning and vaccination status should be more clearly defined/specified within the beef industry to create industry standards. Third-party verification may be necessary to increase credibility of weaning claims.

Calves originating from Alberta received premiums. This result was expected as two thirds of Canadian fed cattle production and 98% federally inspected slaughter in the west (BC, AB, SK, and MB) occurs in Alberta (Canfax, 2020). Premiums were also seen for steer calves originating from Saskatchewan which ranks second to Alberta in Western Canadian feedlot capacity with 10 feedlots with one-time bunk capacities exceeding 1,000 head for a total feeding capacity of 104,500 head (Canfax, 2021). Sourcing calves from Alberta where the majority of cattle feeding occurs may decrease transportation costs for buyers. The expected fed price influenced feeder calf prices, as the expected fed price increased, so did the price of feeder calves. The expected fed cattle price is considered by buyers when deciding how much to pay for feeder calves as it gives insight into the expected value of the calves once they reach finished weight. Results and coefficient estimates for the futures variable are similar to US research by Bulut and Lawrence (2007) and Zimmerman (2010).

Producers may want to limit the number of days between the sale and delivery date, as results show feeder calf prices are discounted for each additional day until delivery. The average days to delivery was 34 days in 2020 which is estimated to result in a discount of $1.60 per cwt for steer lots. The marketing week variable showed calves marketed early in the fall run (September to early October) receive a higher price than those marketed later (late October, November and December). There is a tradeoff that producers will need to consider. For example, a producer may sell calves early in September and receive a premium, but not deliver until early November. The days between sale and delivery date would result in a discount that exceeds the premium from marketing earlier. Producers should consider their options and decide what works best for their operation when choosing which week to market calves and the number of days between the sale and delivery date. The discount applied to a larger number of days to delivery is relatively small and therefore may not be the main factor driving producers' decisions.

Overall, the significance for the value-added variables (EU Eligibility, Age Verification, and VBP+) is low across the models. However, in the more recent years of the study the EU (2019 and 2020 models) and VBP+ (2020 model) variable for the steer models showed statistically significant positive coefficient estimates, this may suggest these variables are gaining recognition in the market. The US beef industry has done a great job adding value for producers marketing calves online, specifically through the Superior Livestock Auction programs. Research supports that these programs are creating value and adding premiums for sellers (McCabe, 2018; Zimmerman, 2010; Zimmerman et al., 2012). SLA has clearly defined regulations and protocol for each value-added program, they utilize third-party verification as well as signed affidavits to ensure that information reported and claims made on lot listing reports are correct. Programs with third-party verification consistently extract premiums.

In September 2020, VBP+ published a fact sheet to provide producers information on how to correctly list calves originating from a VBP+ certified operation. The fact sheet includes terms that should be avoided when listing VBP+ certified calves, also included is a VBP+ certification card that can be filled out and attached to lot listings (VBP+, 2020). Providing producers with information to correctly identify value-added attributes such as VBP+ when marketing their calves is an example of how the industry is coordinating to decrease information asymmetry between the buyer and seller. Canadian online auction markets are moving in the right direction as TEAM held its first online VBP+ only sale on September 24, 2021 with 71 lots (7,031 head). Having an exclusively VBP+ sale provides a more concentrated buying opportunity for buyers seeking to purchase calves from a VBP+ certified operation.

From the results presented in this thesis the two value-added variables with the most significance are EU eligibility and age verification. Perhaps this could be attributed to the fact that for calves marketed as EU eligible buyers require a signed affidavit from the producer to ensure the claims made are accurate and true. It is not surprising that no statistically significant coefficient results were present from 2016 to 2018 for the EU variable, as CETA was only ratified in 2017. EU eligible cattle may also be purchased by feedlots for domestic natural programs such as A & W and may be of higher value due to the increased export potential. Buyers may be willing to pay more for EU eligible calves because they have confidence in the verification of the signed affidavit.

Age verification showed some significance in the steer models. To age verify calves producers must report birthdates and tag numbers to the CCIA. Age verification may be a procedure that continues to decrease in use, as the data supports the total percent of age verified lots has been decreasing over the last five years. Age verification is not mandatory in Canada and as export countries lift age restrictions on Canadian beef it is possible that age verification may not bring significant value to producers moving forward. In May of 2019, Japan lifted age restrictions to allow export of cattle that are 30 months of age or older. The decrease in premium for age verified steers from 2017 ($1.43/cwt) to 2019 ($0.88/cwt) and no premium offered in 2020, may be the result of relaxation in age-related export restrictions.

These results are creating a better understanding of how value-added attributes are valued in Western Canadian online feeder calf sales and suggest that third-party verification may be required for producers to receive higher and more consistent premiums. Research by Schumacher et al. (2012) on how US cattle feeders value health claims, found that approximately 60% of feedlots would pay more for third-party certified health claims than for seller-certified health claims. Third-party verification may increase a buyer's confidence in claims made on lot listing reports, and therefore they may be willing to pay higher premiums for these attributes.

Overall, some of the most important implications of this research that producers can apply when marketing their cattle are providing as much accurate and specific information on the management of their calves and selling in larger lot sizes with more even weight variation. There may also be need for third-party verification for value-added attributes for producers to receive premiums for adopting these practices.

Chapter 9. Summary and Conclusion

9.1 Contribution to Current Research

This research is the first in Canada to use a hedonic pricing model and OLS regression to analyze price determinants for feeder calves sold via online auction in Western Canada over multiple years. This thesis serves as an important contribution to research in this area and will provide a foundation for future research on feeder calf price determinants. The model has been clearly defined to encourage future research in this area utilizing hedonic pricing models and OLS regression. Clearly defining the limitations of this research may encourage research in areas not covered within this thesis.

9.2 Limitations

Although this research included many valuable attributes that influence the sale price of feeder calves there are limitations within the chosen attributes as well as the scope of this project. Analyzing data from online auction sales is possible because of the lot listing reports with lot attributes and details, but manual entry of the data is labour intensive. Only five years of data from the months of August to December were included in the analysis due to the time burden associated with manual entry of lot details. Today many of the live auctions are pre-sorted and broadcast online, so there is potential to have someone watch the broadcast and record information announced by the auctioneer to create a database, but this would be labour intensive to implement. In the US Pfizer Animal Health maintains a database of sales results for SLA and shares the information for research (Zimmerman, 2010). Access to data for analysis may be a major barrier for future research in Canada. The Canadian beef industry needs to collaborate with auction companies to have better access to auction data and provide the data needed to continue researching price determinants for feeder calves.

A few attributes included as independent variables in previous studies were missed in the current study specifically, the presence of horns, breed, and vaccination programs. Percentage of horns was a field in TEAM lot listing descriptions, but DLMS and SALE do not include a field for horns. Breed reporting varied significantly between auction companies. DLMS includes separate fields for breed, colour and herd make up on lot listing reports. TEAM only includes a percent of breed make up category, where producers often list only the colour or only the breed of calves, but not both. In much of the existing research breed is included as an independent variable, but due to inconsistencies in breed reporting and multiple crossbred calves in the current study a hide colour variable was used as a proxy for breed.

Vaccination programs have been extensively analyzed in the US literature due to more defined vaccination protocols and programs. For Canada, lot listing descriptions provide registered product names administered, but do not always include details on when the vaccines were given, and some lot descriptions use generic wording such as “full herd health” with no specifics on products used. With so much variation between lots, no defined terms and no third-party certification, the decision was made to exclude vaccinations from the current study. Creating vaccination categories and analyzing individual health programs for each lot of calves was not a research objective of this study and therefore no health attribute was included in the model.

There is no verification of claims made on lot listing reports, a mention of age verification, EU eligibility or VBP+ is not the same as a third-party verified claim. Therefore, the limitation is to take information as given, but to be aware no third-party verification exists for attribute claims To verify lot information prospective buyers would need to contact the listing agent to discuss claims made and ask for verification. In discussions with industry stakeholders, we learned that without certification feedlot owners will pay the cost to re-vaccinate all calves on intake rather than take the risk of a disease outbreak. Within industry discussion it was shared that some buyers are willing to pay extra cents per pound for signed affidavits for lots with EU or natural claims. There is no way to verify which lots received these extra premiums, but it is important to note that these types of transactions may be occurring after the auction (M. Downing, personal communication, May 17, 2021).

9.3 Areas for Further Research

Future studies on the price determinants for feeder calf attributes could include a longer timeframe (more years or more months) as well as additional model variables. The annual models are helpful in identifying changing preferences year to year. Ideally the database created for this study should be regularly updated to allow for future analysis. Additional model variables that may be included in future studies include seller reputation, BRD (Bovine Respiratory Disease) vaccination, horns, breed, and replacement heifer quality. A reputation or repeat seller variable could be included in the model to see if repeat online sellers receive higher prices. Seller reputation has been shown to influence feeder calf prices (Schulz et al, 2015). A BRD vaccination binary variable could be created based on the products named in the lot listings (i.e., if the 'veterinary work' field included a registered product known for protection against bovine respiratory disease the lot would be categorized as BRD vaccinated). Including attributes on health programs in the model could increase the explanatory power of the model. In much of the existing US research health is a major factor influencing the price of weaned calves and is a significant model variable.

The presence of horns is a variable that could be created for lots sold via TEAM, as they are the only online auction company currently reporting on presence of horns. The presence of horns may not be as important in western Canadian online auctions due to the large percent of cattle with Angus influence (68% of lots in the database), Angus cattle are genetically polled. To date there are no known studies that have included an independent variable to estimate the price effect of replacement quality heifers. It may be a challenge to expand research as at this time there is no way to identify the buyer's intent when purchasing heifers just from the lot listing and sale data. Future research could include a replacement heifer binary variable. Some lots include the terms "replacement quality" or "no heifers kept back" in the comment section of the lot description, these terms could be an indication that heifers in the lot have replacement potential. Specific breed analysis could be included in future research. However, for this to be possible, auction companies need to improve the consistency of breed information collected for each lot. Currently the breed and herd make up categories include multiple crossbred combinations or no specific breeds reported.

The consigner's location could be used to create a distance variable which could estimate if buyers are willing to pay premiums for calves located closer to concentrated feedlot areas, such as southern Alberta's 'feedlot alley'. Using sequence number of the lot to create a variable for which quarter of the sale a lot sold may be a way to assess if sale order influences price, this was done in research by Schulz et al. (2009). A visual evaluation of the lots based on pictures or videos provided with lot listing reports could be used to include a variable to analyze the quality of the lot, and assess factors such as if there are frozen ears or if the calves are in good, clean condition (i.e. no tag in their coat).

9.4 Conclusions

This research has developed a hedonic pricing model with 17 independent variables based on previous literature and industry interviews to evaluate price determinants for Western Canadian feeder calves marketed via online auction. Future research could use this study as a foundation to further expand the model presented in this thesis. Similar to previous US studies, certain traditional attributes such as base weight, lot size, weight variation, hide colour and sex consistently influence feeder calf prices. The value associated with market-based attributes such as EU eligibility, age verification, weaning and VBP+ are more variable in significance and coefficient estimates than the traditional attributes. These results cannot be directly compared to those found in US research, but varied, insignificant results suggest a need for third-party verification on value-added claims. For value-added variables such as VBP+, premiums were only seen for 2020, it is important to continue analysis for future years to see if this premium continues. US studies have shown significant premiums for verified value-added claims (Bulut & Lawrence, 2007; Seeger et al., 2011; Zimmerman et al., 2012). Over the five-year timeframe the estimated value and significance for each attribute varies slightly depending on external factors influencing the yearly feeder calf market. As stated in Blank et al. (2009) there is variability in attribute significance between steer and heifer models as well as over different time periods. Each model year can tell a different story of what the current cattle market was, and which attributes were valued the most by buyers during that time. This study has created a foundation for retrospective analysis to give an indication of what buyers consistently look for when purchasing feeder calves. Overall, this research has provided insight for the Western Canadian beef industry on how different feeder calf attributes are valued on the market. The main attributes that should be considered by producers when marketing calves are weight, lot size, weight uniformity, providing implant information, marketing week, and days to delivery. Cow-calf producers can utilize information from this research when marketing their feeder calves to try to extract premiums or avoid discounts when listing calves for sale.

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APPENDIX A: 2020 LOT LISTING REPORT EXAMPLES FOR TEAM, DLMS, AND SALE

Note: The consigner and listing agent names have been removed

TEAM

Sequence #32
Lot #42

Total head:	**105**	Consignor:	
Sex:	**Heifers**	Location of Cattle:	**Mamit Lake, BC**
Avg. Weight:	**540**	Described by:	
Min. Weight:	**480**	Agent:	
Max. Weight:	**600**	Bulls: **0** Stags: **0** Horns: **0**	

Breed Description (%)		Frame Size & Quality (%)	Lrg	Med	Sm	Body Condition (%)	
60	Red/RBF/RNK					Green:	**0**
40	Black/BBF/BWF	Good:	**0**	**80**	**20**	Light Flesh:	**50**
		Med:	**0**	**0**	**0**	Medium Flesh:	**50**
		Plain:	**0**	**0**	**0**	Heavy Flesh:	**0**

Veterinary Work:	**7-Way, Ivomec & Ralgro @ branding**
Age Verified:	**Yes**
Implants:	**Yes**
Bid Basis:	**FOB Ranch**
Price Slide:	**.12**
Feeding Program:	**With mothers on grass**
Weigh Location:	**Ranch scale**
Weigh Conditions:	**Gather, wean and sort from 1000 calves, weigh less 2%**
Delivery:	**OCTOBER 30**
General Comments:	**Middle cut of red and black heifer calves from Good calves! Will sort +/- for loads.**
Currency:	**$CDN**

DLMS

Lot Detail Information

Sequence #: **24**	Lot #: **40**	Consignor:	****October Delivery****
Head:	**90**	FieldMan:	
Color:	**Red/Red Baldie**	Listing Market:	**NLS Lloydminster**
Sex:	**Str. Calves**	Age Verified:	
Breed:	**Simm X/Angus X**	Base Weight:	**675**
Flesh:	**Light-Medium**	Min Weight:	**600**
Shrink:	**3.5 %**	Max Weight:	**750**
Price Slide:	**0.10**	Estimated Yield:	**0**
SlideType #:	**OVER/UNDER**	Estimated Grade:	

Frame Size & Quality (%)

	Large	Medium	Small
Good	**40**	**60**	**0**
Medium	**0**	**0**	**0**
Plain	**0**	**0**	**0**

Herd Makeup (%)

Herd Makeup	Percentage
Black, Tan & Silver	**5 %**
Simmental X (Red & Red Baldie)	**95 %**

Additional Lot Details

Purchase subject to clearing:	**Y**
Yardage:	**N**
Location of Cattle:	**Dewberry, AB.**
Feed Program:	**Cows and grass.**
Veterinary Work:	**7 Way, 4 Way, Ivomec and Ralgro prior to grass. Cow herd on full herd health.**
Weighing Conditions:	**Sort and haul 20 miles to a truck scale. Less 3.5%.**
Cut Out Options:	**A.N.R.P**
F.O.B:	**Farm**
Payment Terms:	**Cattle purchases are subject to standard payment and clearing charges of the listing market**
Delivery Date Range:	**October 28, 2020 -- October 31, 2020**
General Comments:	**Very good set of Simmental sired steer calves. Lots of stretch. Will get one even load of the bigger end calves.**

SALE

Lot Detail Information

Sequence #: **115**	Lot #: **113**	Consignor:	
Head:	**200**	FieldMan:	
Color:	**80%BLK/BBF 20%RED/RBF**	Listing Market:	
Sex:	**STEERS**	Age Verified:	
Breed:	**BLACK ANGUS**	Base Weight:	**560**
Flesh:	**50%LIGHT 50%MEDIUM**	Min Weight:	**500**
Shrink:	**3 %**	Max Weight:	**700**
Price Slide:	**0.15**	Estimated Yield:	
SlideType #:		Estimated Grade:	

Frame Size & Quality (%)

	Large	Medium	Small
Good	**0**	**0**	**0**
Medium	**0**	**0**	**0**
Plain	**0**	**0**	**0**

Herd Makeup (%)

Herd Makeup	Percentage
Frame Size: 50%MEDIUM 50%LARGE	**1 %**
Quality: 100%GOOD	**1 %**

Additional Lot Details

Purchase subject to clearing:	
Yardage:	
Location of Cattle:	**NANTON. AB**
Feed Program:	**GRASS & MOTHER'S MILK**
Veterinary Work:	**FULL HERD HEALTH. BOVISHIELD GOLD ONE SHOT. 8WAY/SOMNUGEN. AGE VERIFIED. NO IMPLANTS. ZOETIS SELECT VAC GOLD PLUS. KNIFE CUT. EU CERTIFIED**
Weighing Conditions:	**GATHER IN AM. SORT AND WEIGHED ON GROUND AT SCALE AT CORRAL**
Cut Out Options:	
F.O.B:	**RANCH CORRAL - Scale Location: RANCH WEST OF NANTON**
Payment Terms:	**Cattle purchases are subject to standard payment and clearing charges of the listing market**
Delivery Date Range:	**October 28, 2020 -- October 29, 2020**
General Comments:	**HERE IS A VERY NICE SET OF STEER CALVES. YOU ARE GETTING THE TOP 200HEAD. DON'T MISS OUT. ANYTHING NOT RIGHT WILL BE SORTED OFF. STEERS ARE NOW ANGUS TAG CERTIFIED.**

APPENDIX B: COEFFICIENT ESTIMATES FOR POOLED HEDONIC PRICING MODEL SEMI-LOG FORM, 2016 TO 2020

		Steers - 400 to 800lb			Heifers - 400 to 800lb		
Characteristic	**Variable Description**	**Observ. (lots)**	**Coefficient**	**P-Value (P>|t|)**	**Observ. (lots)**	**Coefficient**	**P-Value (P>|t|)**
Intercept	Intercept	3,235	4.6984	< 0.0001	1631	4.3755	< 0.0001
2016	Binary variable for year	556	Base		289	Base	
2017	Binary variable for year	603	0.1149	< 0.0001	297	0.1063	< 0.0001
2018	Binary variable for year	637	0.0914	< 0.0001	347	0.0641	< 0.0001
2019	Binary variable for year	706	0.0584	< 0.0001	339	0.0183	0.008
2020	Binary variable for year	733	0.0764	< 0.0001	359	0.0530	< 0.0001
Lot Size	Number of head in a lot	3,235	0.0002	< 0.0001	1631	0.0003	< 0.0001
$(\text{Lot Size})^2$	Number of head in a lot squared	3,235	0.0000	< 0.0001	1631	0.0000	< 0.0001
Weight	Avg. base weight (lb) of lot	3,235	-0.0005	< 0.0001	1631	-0.0005	< 0.0001
$(\text{Weight})^2$	Avg. base weight (lb) of lot squared	3,235	0.0000	< 0.0001	1631	0.0000	< 0.0001
Weight Variation	Uneven (100-199 lb spread)	2137	Base		1111	Base	
	Even (less than 100 lb spread)	545	0.0061	< 0.0001	247	0.0128	< 0.0001
	Very Uneven (over 200 lb spread)	553	-0.0117	< 0.0001	273	-0.0033	0.234
Week	Week number of sale	3,235	-0.0015	< 0.0001	1631	-0.0013	0.030
Frame	Medium		Base			Base	
	Small to Small-Medium Mix	242	-0.0078	0.001	204	-0.0110	< 0.0001
	Medium-Large Mix	2179	0.0046	0.002	956	0.0046	0.059
Flesh	Medium to Heavy	1712	Base		863	Base	
	Light-Medium Mix	699	-0.0029	0.041	337	-0.0033	0.163
	Light	824	0.0010	0.498	431	0.0041	0.085
Implant	Not Implanted	1342	Base		345	Base	
	Implanted	1150	-0.0025	0.064	783	-0.0045	0.065
	Not Specified	743	-0.0077	< 0.0001	503	-0.0163	< 0.0001
VBP+ Operation	Not Specified	2983	Base		1522	Base	
	Operation Mentioned VBP+	252	-0.0026	0.195	109	0.0069	0.077
Age Verification	Not Specified	1600	Base		786	Base	
	Lot mentions age verification	1635	0.0034	0.006	845	0.0021	0.291
EU Eligible	Not Specified	3085	Base		1565	Base	
	Lot mentions EU eligibility	150	0.0142	< 0.0001	66	0.0072	0.102
Weaned	Not weaned	3052	Base		1534	Base	
	Weaned	183	-0.0001	0.977	97	-0.0051	0.387
Hide/Coat Colour	Black	1210	Base		527	Base	
	Charolais Influence	326	0.0250	< 0.0001	331	0.0287	< 0.0001
	Red	581	-0.0019	0.243	226	0.0033	0.317
	Mixed	1118	-0.0043	0.001	547	-0.0039	0.082
Location	British Columbia	250	Base		139	Base	
	Alberta	2020	0.0166	< 0.0001	1154	0.0083	0.016
	Saskatchewan	965	0.0086	0.001	338	-0.0021	0.604
Days to Delivery	Days between sale date and delivery date	3235	-0.0004	< 0.0001	1631	-0.0003	< 0.0001
Expected Fed Price	Expected fed price as per LPI	3235	0.0038	< 0.0001	1631	0.0054	< 0.0001
Analysis of Variance and Homoscedasticity		**Adj. R^2 Value:** 0.8662			**Adj. R^2 Value:** 0.8423		
		Root MSE: 0.03118			**Root MSE: 0.3588**		
		White Test Results: P> Chi2 < 0.0001			**White Test Results:** P> Chi2 < 0.0001		
		DF = 395	Chi-Square = 1300.45		DF = 395	Chi-Square = 668.57	
		Estimated with Robust Standard Errors			Estimated with Robust Standard Errors		

APPENDIX C: DATA ENTRY GUIDELINES, INCLUDING ASSUMPTIONS MADE

1. Consigner: if the ranch name and names of the individuals are both present, record in this format "ranch name, name of individuals".

2. Frame size: if the percentages are available input the values exactly as per the listing, if the field says "medium to light" with no exact percentages given, enter as 50% light and 50% medium, same for "medium to large", enter as 50% medium and 50% large

3. Flesh: most do not have percentages, but if there is a percentage round up to the choice that the percentage is highest, or if they are close to half and half say "medium to light"

    a. 70%MEDIUM 30%HEAVY: in this case 70 >30 so we say that these calves are medium flesh

    b. 50% medium, 50% light = medium to light

    c. 60% medium, 40% light =medium to light

    d. 70% medium, 30% light = medium

    e. Green = light

4. Colour: The colour fields to choose from are black, red, black and black and white-face (BLK/BWF), red and red and white-faced (Red/RWF), tan, grey or silver, BWF, RWF, Hereford, Charolais (colours are grey, white, tan) and mix. Most listings give a percentage, if something falls outside of the specific colours listed, it can go into the mix category.

    a. 90%BLK 10%BBF/RED/RWF. For example, if there are three or more colours listed in the same line or percent e.g. 10% BBF/RED/RWF enter as 10% mix

    b. 60% Red, 40% BWF/RWF. In this case there are only two colours under the 40%, divide equally and enter as 20% BLK/BWF and 20% RED/RWF

    c. 40% Tan 60% BLK/BWF

    d. When no breed is specified enter as "Not Specified" in the 'Breed' field

    e. If no colour is specified and breed is Simm X or Simm Angus X we assume 100% BLK/BWF

5. Feed: Grass and mothers' milk can be the answer even if it is specific of native grass or tame grass. If other additions are included such as mineral or silage or a different feed ration include.

6. Health: Entered verbatim to lot listing. If the words “ralgro” or “implant” or “no implants” was included, a ‘Yes/No’ entry was made in the implant field. If type of castration was reported in the health field, the method was entered in the ‘Castration’ field. This field also carried details on whether or not the animals in the lot were age verified, the operation was enrolled in VBP + or if calves were EU eligible.

7. Comments: Entered verbatim except for the percent colour of the calves.

APPENDIX D : INDEPENDENT MODEL VARIBLES VIF VALUES

	Pooled		2016		2017		2018		2019		2020	
Variable	**Steers**	**Heifers**	**Steers**	**Heifers**	**Steers**	**Heifers**	**Steers**	**Heifers**	**Steers**	**Heifers**	**Steers**	**Heifers**
2016	Base	Base										
2017	3.15	3.33										
2018	8.2	10.7*										
2019	7.8	9.2										
2020	6.1	7.1										
Lotsize	2.2	2.2	2.1	2.0	2.3	2.7	2.4	2.4	2.4	2.5	2.2	1.8
Lotsize2	2.1	2.0	2.0	1.9	2.3	2.4	2.3	2.4	2.2	2.4	2.1	1.7
Wt	1.5	1.8	1.6	2.2	1.6	2.0	1.4	1.5	1.5	1.8	1.8	2.0
Wt2	1.1	1.4	1.2	1.7	1.2	1.7	1.1	1.3	1.2	1.4	1.2	1.6
WV_Uneven	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base
WV_Even	1.2	1.1	1.1	1.2	1.2	1.3	1.2	1.2	1.3	1.3	1.3	1.2
WV_Vuneven	1.1	1.2	1.1	1.2	1.2	1.3	1.2	1.2	1.1	1.2	1.1	1.2
Wk	3.2	3.6	2.6	2.8	3.8	4.9	3.0	4.3	3.2	3.9	4.5	5.2
Frame_SM	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base
Frame_M	1.3	1.4	1.4	1.6	1.4	1.6	1.2	1.5	1.3	1.5	1.4	1.4
Frame_ML	1.5	1.5	1.6	1.9	1.5	1.5	1.4	1.5	1.6	1.6	1.6	1.6
Flesh_MH	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base
Flesh_LM	1.2	1.2	1.2	1.3	1.2	1.3	1.2	1.2	1.2	1.3	1.2	1.3
Flesh_L	1.3	1.4	1.4	1.5	1.3	1.5	1.3	1.5	1.4	1.5	1.3	1.4
No_IMP	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base
IMP	1.4	2.0	1.3	2.4	1.4	2.6	1.4	2.0	1.5	2.0	1.5	2.0
IMP_NS	1.5	2.3	1.5	3.1	1.6	3.0	1.4	2.2	1.6	2.4	1.5	2.1
VBP+	1.1	1.2	1.1	1.2	1.0	1.1	1.1	1.2	1.2	1.2	1.3	1.3
AV	1.2	1.3	1.3	1.6	1.3	1.6	1.2	1.2	1.3	1.3	1.3	1.4
EU	1.2	1.1			1.1	1.1	1.2	1.2	1.2	1.2	1.4	1.2
Wean	1.6	1.9	1.2	1.4	2.0	3.3	1.6	2.1	1.8	1.9	1.7	2.3
Hide_Blk	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base
Hide_Char	1.2	1.7	1.3	1.7	1.3	1.8	1.3	1.6	1.3	1.7	1.3	1.8
Hide_Red	1.3	1.3	1.3	1.4	1.4	1.4	1.3	1.4	1.4	1.4	1.3	1.4
Hide_Mix	1.3	1.5	1.4	1.6	1.3	1.6	1.4	1.4	1.3	1.5	1.3	1.5
Loc_BC	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base
Loc_AB	3.8	3.1	4.1	3.1	4.0	3.1	4.7	3.6	3.6	2.8	3.9	4.1
Loc_SK	3.8	3.1	4.0	2.9	4.0	3.1	4.8	3.7	3.5	2.7	4.0	4.0
DTD	2.4	2.3	2.5	2.0	2.4	2.4	2.4	2.5	2.5	2.8	2.7	2.7
Exp_Fed_P	6.3	8.4	1.9	2.4	1.2	1.1	1.5	2.1	1.1	1.5	2.1	3.1

* Indicates VIF Value is over 10